RULES
R005-2024

**CHINA CLASSIFICATION SOCIETY**

# RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

# 2024

Effective from 1 July 2024

**Beijing**

# EXPLANATION

On the basis of the Rules for Construction of Sea-going Ships Engaged on Domestic Voyages (2023), the Rules for Construction of Sea-going Ships Engaged on Domestic Voyage (2024) incorporates:

(1) 2024 Amendments to the Rules for Construction of Sea-going Ships Engaged on Domestic Voyages, effective on 1 July 2024.

CHINA CLASSIFICATION SOCIETY

# RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

## 2024

## PART ONE GENERAL

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**PART ONE GENERAL**
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# CHAPTER 1 GENERAL

## Section 1 APPLICATION

### 1.1.1 Application

1.1.1.1 The Rules apply to sea-going steel ships of 20 m or over in length which are engaged on domestic voyages.

1.1.1.2 The Rules apply to new ships. All ships constructed before the date of entry into force of the Rules are to continue to comply with the requirements previously applicable to them. For ships which have undergone modification of a major character, the modified and related portions are to comply with the new Rules. The previous Rules are still applicable to those ships of which the midship section plan or an equivalent structural plan has been approved.

1.1.1.3 If ships are involved in following aspects, relevant requirements of the Rules for Classification of Sea-going Steel Ships of China Classification Society (hereinafter referred to as CCS) are to be complied with:

(1) Navigation in ice;

(2) Steam control system;

(3) Cargo refrigerating installation;

(4) Machinery automatic control system.

1.1.1.4 For ships of special type, special function or special purpose, relevant supplementary provisions in PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships are to be complied with.

1.1.1.5 Materials and welding are to comply with CCS Rules for Materials and Welding.

1.1.1.6 The Rules, unless expressly provided otherwise, do not apply to:

(1) military vessels;

(2) wooden ships;

(3) pleasure yachts

(4) high speed craft;

(5) small waterplane area craft;

(6) sailing boats;

(7) fishing vessels.

## Section 2 RULES

### 1.2.1 Rules

1.2.1.1 Rules are technical requirements that have entire content. The aim of the rules is to ensure the safety and quality to be controlled to an appropriate level, and to be generally acknowledged.

1.2.1.2 “Special rules” are technical provisions that have special content and will be used in combination with the Rules.

1.2.1.3 For those not covered in present rules, or the principled requirements therein which need to be further defined in details, or where specific applicability of the rules is needed, or for novel ships or equipment or systems, appropriate guidelines will be developed. Where any “guidelines” are referred to in the rules, the paragraphs related to in such “guidelines” constitute requirements of the rules.

1.2.1.4 CCS COMPASS computer software system covers structural calculation and evaluation, ship characteristics, calculation of shafting vibration and strength and calculation of short-circuit current. The computer software plays an essential role in plan approval and surveys during and after construction.

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

1.2.1.6 The right of interpretation on the rules published by CCS is to be left solely to CCS Headquarters.

**1.2.2 Rules development**

1.2.2.1 The main input for development of the rules is as follows:

(1) experience in application;

(2) relevant scientific theories and research findings;

(3) the applicable part of the relevant conventions, codes and resolutions adopted by IMO (International Maritime Organization),unified requirements by IACS (International Association of Classification Societies) and relevant statutory requirements by the Chinese Government.

1.2.2.2 The drafts of rules or their amendments will be distributed to the Administration, designers, shipbuilders and manufacturers, survey units, owners, research institutes and universities related to ships and marine products for comments.

1.2.2.3 The drafts of CCS rules or their amendments are to be further supplemented and improved based on analysis of the expert comments or recommendations from the above-mentioned sources, followed by a final review by CCS Technical Committee or its subcommittee(s), and then issued after being approved and signed by CCS President.

1.2.2.4 Where the Rules needs to be amended, as shown by experience in application, safety aspects covered by investigation of accidents, or due to entry into force of relevant statutory requirements by Chinese Government, CCS will directly publish amendments thereto.

**1.2.3 Entry into force of rules**

1.2.3.1 Unless stated otherwise, the rules (including their amendments) will generally come into force in 6 months after being published. The effective date will be indicated on the first page of the corresponding PART or on the title page of the publication.

1.2.3.2 Unless stated specially, the rules are applicable to newbuildings.

1.2.3.3 With the consent of the shipyard and the owner, the requirements of the new rules may be adopted for the ship under construction; and where the requirements in the new rules are reasonable and practicable, it may be agreed that these requirements be adopted for the ship under construction. In any case, this is to be indicated in the corresponding technical documents.

1.2.3.4 The date of entry into force of the rules is subject only to the date of approval for publishing the rules, not to the date of entry into force of any other statutory requirements.

## Section 3 DEFINITIONS

**1.3.1 Definitions**

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

(1) Chinese water areas mean the coastline ports, inland waters, territorial seas and all other water areas under the jurisdiction of the People’s Republic of China.

(2) Domestic voyage means a voyage in Chinese water areas. When ships navigate in Chinese water areas or special areas or a certain service area, they are to comply with the applicable national regulations established by the Administrations of the Chinese government.

(3) Service areas means the areas defined in the Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages developed by Maritime Safety Administration of the People’s Republic of China.

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

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

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

(7) A ro-ro passenger ship is a passenger ship with ro-ro cargo spaces or special category spaces to carry ro-ro cargo.

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

(9) Oil means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than those petrochemicals which are subject to the provisions of Chapter 3 of Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages).

(10) An oil tanker is a ship which is constructed primarily to carry oil in bulk and includes ship types such as combination carriers (ore/oil ships etc.).
(11) A ro-ro ship is a ship which utilizes a loading ramp to enable wheeled vehicles to be rolled on and rolled off the ship.
(12) A container ship is a ship constructed for the carriage of containers in holds and on deck.
(13) A bulk carrier is a ship which is constructed generally with single deck, topside tanks, hopper side tanks and double bottoms in cargo spaces, and is intended primarily to carry dry cargo in bulk.
(14) Self-propelled ship is a ship with mechanical propelling unit mainly for the purpose of navigation.
(15)A new ship means a ship contracted for construction on or after the date of entry into force of the Rules.
1.3.1.2 Application
(1) When applying the rules, for an open sea service ship designed for the service in the sea area within 200 nautical miles off the shore, the technical requirements for greater coastal service may apply; for a greater coastal service ship designed for the service in the sea area within 20 nautical miles off the shore, the technical requirements for coastal service may apply.

# Section 4 SUBMISSION AND EXAMINATION OF PLANS

### 1.4.1 Examination of plans and documents

1.4.1.1 Prior to commencement of construction of the ship, the applicant is to submit the application together with the plans and documents in triplicate according to the relevant requirements of the Rules to a designated plan approval unit for examination. Where the plans will be submitted in batches, at least the necessary hull plans and documents are to be submitted first.
Copies of the plans to be submitted for approval for a series of ships or ships to be additionally constructed within one year in accordance with the approved main structural plans may be reduced or such submission exempted according to the specific conditions.
1.4.1.2 The ship's list of survey and test items, as well as the technical documents, such as welding procedure, welding specifications, NDT diagrams, installation procedure of machinery (excluding reasonable alignment of shafting), inclination testing programme, and mooring test and sea trial programme, are to be submitted to the attending Surveyors for examination.
1.4.1.3 Necessary scantlings and relevant data as required by the Rules are to be indicated on the plans and documents submitted.
1.4.1.4 The term "approval" means that the plans and documents have been examined and found in compliance with the rules. The approval of plans and documents covers only the items as required by the rules, excluding any items not required by the rules.
1.4.1.5 The plans and documents as deemed to comply with the Rules upon examination, are to be stamped with APPROVED seal. The approval conditions and restrictions may be written on the plans and documents, or stated in the plan approval letters with appropriate notes being added on the plans and documents.
1.4.1.6 The term "Used for information" means that the plans and documents have been examined and only used as supporting information to the approval of other relevant plans and documents.

### 1.4.2 Validity of approved plans

1.4.2.1 The approved plans are valid only for construction in the designated shipyard, the construction project number or the number of ships to be constructed as specified in the application or contract/agreement for plan approval.
1.4.2.2 The approved plans will be invalid automatically in one of the following cases:
(1) after 4 years since the approval date of plans;
(2) after 1 year since the approval date of sectional plans of newbuildings where the entry into force of new rules including their amendments affects such plans;
(3) the construction of the ship(s) for the project number or the number of ships as specified in the application or contract/agreement for plan approval has been completed;

(4) the approved shipyard or construction project number has been changed, or the number of ships constructed is exceeded.

1.4.2.3 Where the statutory requirements of the Chinese Administration or the international conventions, codes accepted by it and the entry into force of the amendments thereto affect the validity of the approved plans, the approved statutory plans will be invalid automatically.




CHINA CLASSIFICATION SOCIETY

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## 2024

## PART TWO HULL

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# CHAPTER 1 GENERAL

## Section 1 GENERAL PROVISIONS

### 1.1.1 Application

1.1.1.1 This PART applies to sea-going steel ships of all welded construction.

1.1.1.2 In addition, the hull is to comply with the applicable requirements in PART ONE of the Rules.

### 1.1.2 Definitions

1.1.2.1 Length of ship $L$ (in m), i.e. the Rule length, is the distance measured on the waterline at the scantling draught from the forward side of the stem to the aft side of the rudder post, or to the centre of the rudder stock if there is no rudder post. $L$ is not to be less than 96%, and need not be greater than 97%, of the extreme length on the waterline at the scantling draught. In ships with unusual stern and bow arrangement, the length $L$ is to be specially considered.

For pontoon hulls, $L$ is the distance on the waterline at the scantling draught from the forward side of the fore end plate to the aft side of the aft end plate.

For ships without rudder stocks (such as ships provided with azimuth thrusters), $L$ is 97% of the extreme length on the waterline at the scantling draught.

1.1.2.2 Breadth of ship $B$ (in m), is the greatest moulded breadth measured amidships at the scantling draught.

1.1.2.3 Moulded depth $D$ (in m), is the vertical distance measured at the middle of the length $L$ from top of keel to top of the deck beam at side on the uppermost continuous deck. When a rounded gunwale is arranged, the moulded depth is to be measured to the point of intersection of the continued moulded lines of the deck and side shell plating.

1.1.2.4 Draught $d$ (in m) , i.e. the scantling draught, is the vertical distance measured at the middle of the length $L$ from top of keel to the waterline at the scantling draught. Scantling draught at which the strength requirements for the scantlings of the ship are met represents the full load condition. The scantling draught is to be not less than that corresponding to the assigned freeboard.

1.1.2.5 Block coefficient $C_b$ is the moulded block coefficient corresponding to the waterline at the scanting draught, to be determined by the following formula:

$$C_b = \frac{\nabla}{LBd}$$

where: $\nabla$ — moulded displacement, in $m^3$, at scantling draught $d$;

$L$, $B$, $d$ — see 1.1.2.1, 1.1.2.2 and 1.1.2.4 of this Section.

1.1.2.6 Uppermost continuous deck is the uppermost deck which extends from the stem to the stern.

1.1.2.7 Strength deck means:

(1) the uppermost continuous deck;

(2) the superstructure deck extending within 0.5 $L$ amidships, and having a length not less than 0.15 $L$, and the uppermost continuous deck extending outside the region of such a superstructure.

1.1.2.8 Lower decks: The continuous deck next below the uppermost continuous deck is to be named as 2nd deck, and so on. They are generally called lower decks.

1.1.2.9 Bulkhead deck is the highest deck to which the transverse watertight bulkheads extend.

1.1.2.10 Freeboard deck is the deck from which the freeboard is measured.

1.1.2.11 Platform decks are the non-continuous decks below the strength deck, which are not considered to be effective decks for longitudinal strength.

1.1.2.12 Superstructure and deckhouse: Superstructure is an enclosed structure on the uppermost continuous deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth $B$. Forecastle, bridge and poop are regarded as superstructures. All other enclosed structures are to be termed as deckhouses.

1.1.2.13 Long superstructure and short superstructure: A superstructure having a length greater than 0.15 $L$ and not less than 6 times its height is to be termed as a long superstructure, otherwise it is to be regarded as a short superstructure.

1.1.2.14 Long deckhouse and short deckhouse: A deckhouse having a length greater than 0.15 $L$ and not less than 6 times its height is to be termed as a long deckhouse, otherwise it is to be regarded as a short deckhouse.

1.1.2.15 Stowage rate $\gamma$ ($m^3/t$) is the volume of the hold, in $m^3$, excluding the volume contained within the depth of the cargo hatchway, divided by the mass of cargo, in tons, stowed therein.

1.1.2.16 Forward and after perpendiculars: The forward perpendicular is to coincide with the foreside of the stem on the scantling draught waterline on which the length $L$ is measured. The after perpendicular is the perpendicular to the scantling draught waterline at a distance $L$ aft of the fore end.

1.1.2.17 Large openings: A deck opening is to be regarded as a large opening if any of the following conditions applies:

(1) $\frac{b}{B_1} \geq 0.7$;

(2) $\frac{l_H}{l_{BH}} \geq 0.89$;

(3) $\frac{b}{B_1} > 0.6$ and $\frac{l_H}{l_{BH}} > 0.7$.

where: $b$ — breadth of the opening, in m. Where there are several hatches abreast, $b$ is the sum of individual widths of these openings, i.e. $b = b_1 + b_2$, as shown in Figure 1.1.2.17;

$B_1$ — maximum breadth of deck, in m, including opening, measured at the mid-length of the opening;

$l_H$ — length of the hatch, in m;

$l_{BH}$ — distance between centrelines of the deck strips at each end of the opening, in m, as shown in Figure 1.1.2.17. Where there are no further hatches fore or aft of the one under consideration, then $l_{BH}$ is to be measured to the bulkhead.

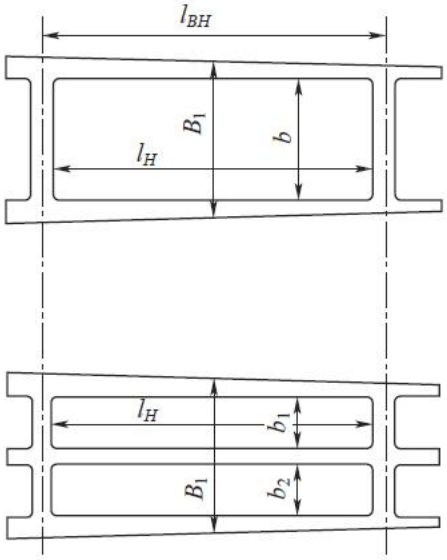



**Figure 1.1.2.17**

1.1.2.18 Primary members: The primary supporting members of hull are regarded as primary members, such as web frames, side stringers, transverses, deck girders, plate floors, bottom girders, bulkhead webs, etc.

1.1.2.19 Secondary members: The stiffeners of the plate are generally regarded as secondary members, i. e. frames, longitudinals, beams, bulkhead stiffeners and members of bracket floors, etc.

1.1.2.20 Load line length $L_L$ (in m) is the ship's length as defined in the Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, PART THREE.

1.1.2.21 Position 1 is as defined in the Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, PART THREE.

1.1.2.22 Position 2 is as defined in the Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, PART THREE.

1.1.2.23 Main frames are side frames between the collision bulkhead and the aft peak bulkhead, and below the lowest deck.

1.1.2.24 Frames in a 'tween deck space are frames between two decks.

1.1.2.25 Fore peak is a compartment situated forward of the collision bulkhead and below the bulkhead deck.

1.1.2.26 Aft peak is a compartment situated aft of the aft watertight bulkhead at the aft end of the ship and below the bulkhead deck or the watertight platform deck.

1.1.2.27 $V$, the maximum service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

# Section 2 HULL STRUCTURAL MEMBERS

### 1.2.1 General requirements

1.2.1.1 Except where otherwise stated, the Rule section modulus or moment of inertia in this PART is the minimum required value of the section in association with attached plating, and the attached plating is assumed as being normal to the web. When the attached plating is not normal to the web and the angle between them is less than 75°, the sectional characteristics (moment of inertia, section modulus and shear area) are to be calculated in respect to the axis parallel to the attached plating. When a structural member is of rolled section(s), its actual section modulus may be approximately determined by the following formula:

$$W = W'\sin\alpha \qquad \text{cm}^3$$

where:

$W'$ — actual section modulus with the attached plating assumed as being normal to the web, in $\text{cm}^3$;

$\alpha$ — angel between web and attached plating, in degrees.

1.2.1.2 Except where otherwise stated in the Rules, holes are not to be cut at random in the structural members specified in this PART.

1.2.1.3 In formulae or tables where only midship and end scantlings are given, the reduction from the midship to the end scantlings is to be effected in as gradual a manner as practicable. At the break of structures, constructional arrangement is to be made to ensure a gradual transition.

1.2.1.4 Unless otherwise stated, any intermediate value between the values listed in the Tables may be obtained by linear interpolation.

1.2.1.5 As commercialized marine plates and rolled sections are not produced in sequential size series and for the purpose of providing an economic and reasonable structural requirement without compromising structural strength, the rounding tolerance for selecting steel plates according to the sizes of structural members as required in this PART is to be based on the following principles:

(1) Where the decimal part of the calculated plate thickness in this PART is 0.25 mm or less, it may be neglected; where it is greater than 0.25 mm but less than 0.75 mm, to be taken as 0.5 mm; where it is 0.75 mm or more, a round number of 1 mm is to be taken.

(2) For a structural member made of rolled section(s), its section modulus with the effective attached plate being taken into account, may be 3% less than the value required in this PART.

(3) When same sizes are taken during construction for a group of members of a same type made of rolled sections adjacent to each other in the same area, their respective section moduli with their effective attached plates being taken into account, are not to be less than the mean value of the values respectively required in this PART for individual members of the group. However, this mean value is not to be less than 95% of the greatest value required in this PART for an individual member of the group.

(4) The above principles (2) and (3) are not to be applied together.

1.2.1.6 Unless otherwise stated, all scantlings given in this PART are to be regarded as the minimum required. When designing structural members, those subject to excessive corrosion or wear and tear in service may be adequately increased in thickness.

1.2.1.7 Local members which may frequently bear the forces resulting from docking, pushing or towing, etc., are to be strengthened appropriately.

### 1.2.2 Attached plating of members

1.2.2.1 The effective sectional area $A$ of attached plating of primary members is to be determined as follows, but is not to be less than the sectional area of the face plate:

(1) For a member attached to plane plating:

$$A = 10\,fbt_p \quad \text{cm}^2$$

(2) For a member attached to corrugated plating and parallel to the corrugations:

$$A = 10\,at \quad \text{cm}^2$$

(3) For a member attached to corrugated plating and at right angles to the corrugations:

$$A = 10\,b_f t_f \quad \text{cm}^2$$

where: $f$ — factor, equal to $0.3(l/b)^{2/3}$, but not to exceed 1;

$b$ — the mean width, in m, of the load-bearing area of primary members;

$l$ — the overall length, in m, of the primary member;

$t_p$ — the mean thickness, in mm, of the attached plating;

$b_f$ — the width, in m, of the face plate of primary members;

$t_f$ — the thickness, in mm, of the face plate of primary members;

$a$ — the width, in m, of corrugated plating flange;

$t$ — the thickness, in mm, of corrugated plating.

1.2.2.2 For secondary members, the width of attached plating is taken as one spacing of the corresponding members.

### 1.2.3 The span point of members

1.2.3.1 Except where otherwise stated, the span used for the calculating of the members in this PART is the effective span between the span points.

1.2.3.2 For primary members, the span point is to be taken at a point $b_e$ distant from the end of the member (See Figure 1.2.3.2):

$$b_e = b_b(1-\frac{d_w}{d_b})$$

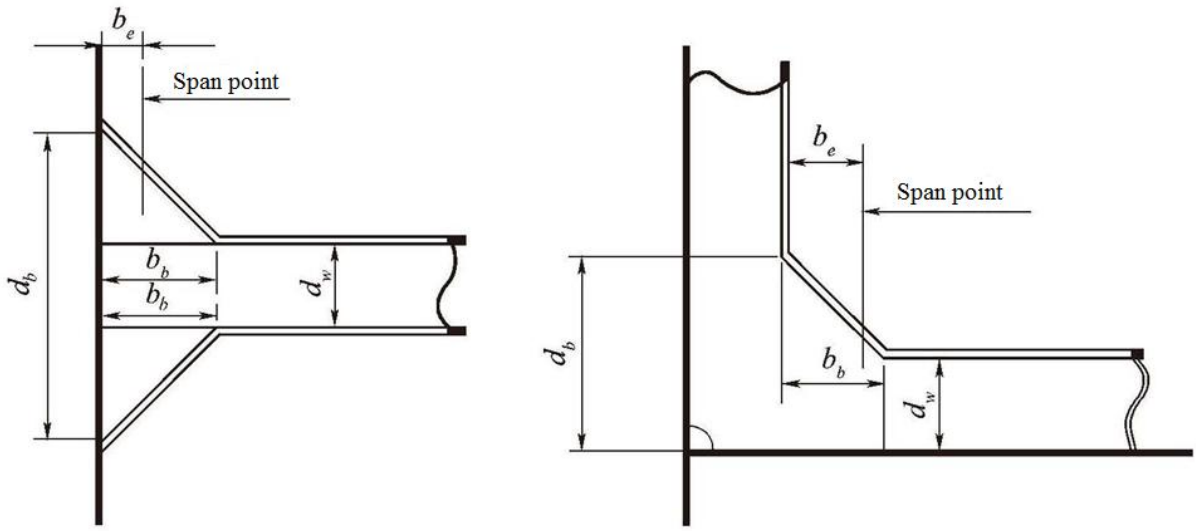



**Figure 1.2.3.2**

1.2.3.3 For span points of secondary members where end brackets are fitted, see Figure 1.2.3.3 (1). Where there is no end bracket, the span point is to be taken at the end of the member (as shown in Figure 1.2.3.3 (2)).

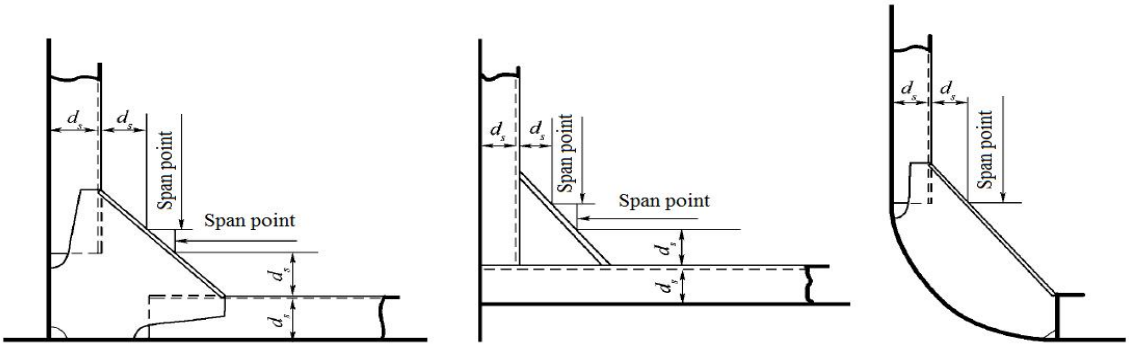



**Figure 1.2.3.3(1)**

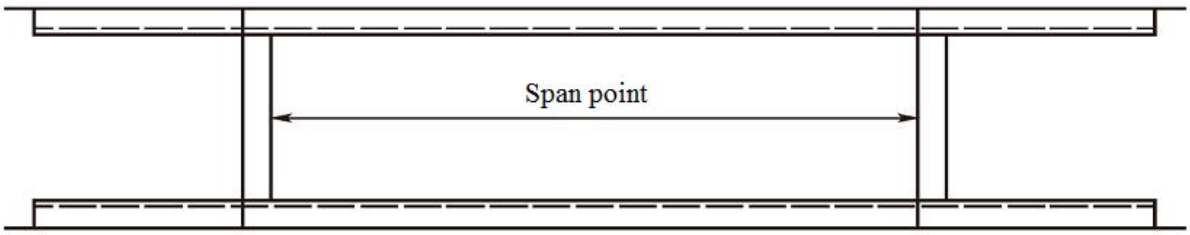



**Figure 1.2.3.3(2)**

1.2.3.4 Unless otherwise specified in this PART, the span of curved members is defined as the chord length between span points.

1.2.3.5 Where the ends of stiffening members are not substantially fixed against rotation and displacement, consideration will be given to the effective span to be used for the stiffener.

### 1.2.4 Geometrical characteristics of members

1.2.4.1 Section area $A_z$, moment of inertia $I$ and section modulus $W$ of rolled sections (including bulb flats, unequal angle bars, and unequal angle bars of unequal thickness) (see Figure 1.2.4.1) together with attached plating are to be calculated by the following formulae:

$$A_z = A_1 + A \qquad \text{cm}^4$$

$$I = I_{x1} + (y_1 - y)^2 A_1 + \frac{At^2}{12} \times 10^{-2} + (0.05\,t + y)^2 A \qquad \text{cm}^4$$

$$W = \frac{I}{0.1h - y} \qquad \text{cm}^3$$

where: $h$ — height of the sections, in mm;

$A_1$ — sectional area of the sections, in cm$^2$;

$I_{x1}$ — moment of self-inertia of the sections, in cm$^4$;

$y_1$ — neutral axis of the sections, in cm;

$A$ — sectional area of the attached plate, in cm$^2$;

$t$ — thickness of the attached plate in mm;

$y$ — neutral axis with attached plate being considered, to be calculated by the following formula:

$$y = \frac{A_1 y_1 - 0.05At}{A_Z} \quad \text{cm}$$

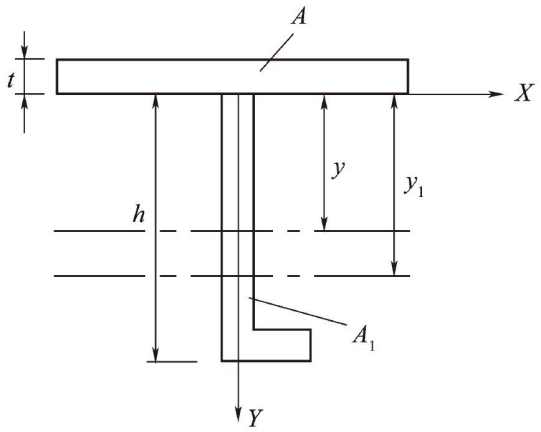



**Figure 1.2.4.1**

1.2.4.2 Where the thickness of both face plate and attached plate of T sections is not greater than 1/10 of web depth, section modulus $W$ and moment of inertia $I$ for T sections with attached plating (see Figure 1.2.4.2) may be calculated by the following formulae:

$$W = \frac{d_w}{10}\left[a + \frac{f_s}{6}\left(1 + \frac{2(A-a)}{2A + f_s}\right)\right] \quad \text{cm}^3$$

$$I = \frac{d_w^2}{100}\left[\frac{1}{3}f_s + \frac{Aa - 0.25f_s^2}{A + a + f_s}\right] \quad \text{cm}^4$$

where: $a$ — sectional area of face plate, in cm$^2$;

$A$ — sectional area of attached plating, in cm$^2$; where $A < a$, it is taken as $A = a$;

$f_s$ — sectional area of web plate, in cm$^2$;

$d_w$ — depth of web, in mm.

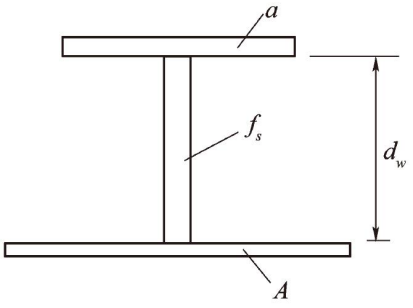



**Figure 1.2.4.2**

1.2.4.3 The section modulus $W$ and moment of inertia $I$ of a corrugation over a spacing $s$ for corrugated bulkheads (see Figure 1.2.4.3) may be calculated by the following formulae:

$$W = d_w t\left(a + \frac{b}{3}\right) \quad \text{cm}^3$$

$$I = \frac{1}{20} d_w^2 t \left( a + \frac{b}{3} \right) \quad \text{cm}^4$$

where: $a$ — width of corrugation flange, in m;

$b$ — width of corrugation web, in m;

$d_w$ — depth of corrugation, in mm;

$t$ — thickness of corrugated bulkhead plating, in mm;

$\alpha$ — angle between web and flange of a corrugation.

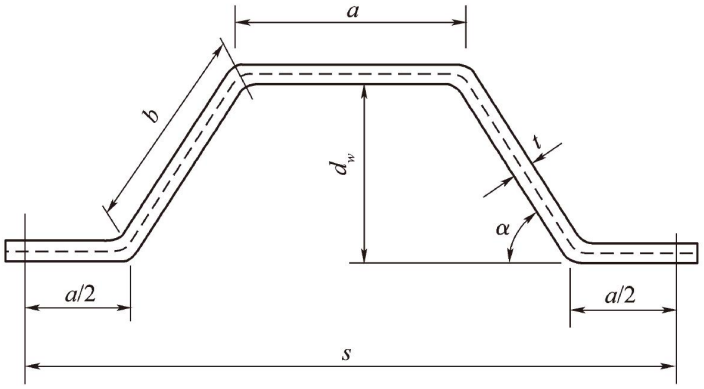



**Figure 1.2.4.3**

1.2.4.4 The section modulus $W$ and moment of inertia $I$ of double skin bulkheads (see Figure 1.2.4.4) may be calculated by the following formulae:

$$W = b \left( fst_p + \frac{bt_w}{6} \right) \times 10^3 \quad \text{cm}^3$$

$$I = 5 \left( fst_p + \frac{bt_w}{6} \right) b^2 \times 10^4 \quad \text{cm}^4$$

where: $b$ — spacing of double skins, in m;

$s$ — average spacing of diaphragms, in m;

$t_p$ — thickness of double skin bulkheads, in mm;

$t_w$ — thickness of web, in mm;

$f$ — factor, the same as specified in 1.2.2.1 of this Chapter.

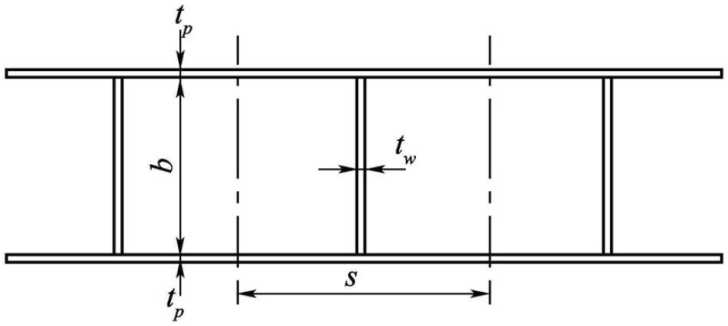



**Figure 1.2.4.4**

1.2.4.5 The minimum radius $r$ of inertia of sectional area of members is to be calculated by the following formula:

$$r = \sqrt{\frac{I}{A}} \quad \text{cm}$$

where: $I$ — minimum moment of inertia of sectional area of members, in cm$^4$;

$A$ — sectional area of members, in cm$^2$.

### 1.2.5 Structural details

1.2.5.1 Primary members are to be so arranged as to ensure effective continuity of structure, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring framing. The connections of the ring framing are to be made of rounded corners having an adequate radius, and the radius of rounded corners is in general not to be less than the web depth of the adjacent members.

1.2.5.2 The web thickness $t_w$ of primary members is not to be less than 0.01 $S_w$, in mm (where $S_w$ = spacing of horizontal stiffeners on primary member web, or depth of unstiffened web, in mm); but not less than 7 mm in dry spaces and not less than 8 mm in tanks. For ships of less than 60 m in length, the web thickness may be reduced by 1 mm. For ships of less than 40 m in length, the web thickness may be reduced by 2 mm.

1.2.5.3 The sectional area $A_f$ of face plate of primary members is not to exceed $d_w t_w/150$, in cm$^2$ (where $d_w$ = depth of primary member web, in mm, $t_w$ = thickness of primary member web, in mm).

1.2.5.4 Primary members are to be supported by tripping brackets. Where the primary members are of symmetrical section, the tripping brackets are to be fitted four secondary member spaces apart and if the width of the face plate of primary members is more than 400 mm, a back bracket is to be provided in way of the tripping bracket. Where the primary members are of asymmetrical section, tripping brackets are to be fitted on one side of the web at alternate secondary members. Tripping brackets are also to be fitted to the primary members in way of concentrated loads. If the ratio of depth to thickness of the web is greater than 55, tripping brackets or stiffeners are to be fitted close to the toes of end brackets.

The height of tripping brackets is to be extended to the face plate of primary members. The breadth is not to be less than 40% of the height. Where the unsupported breadth of the face plate or flange of primary members exceeds 15 $t$ ($t$ being thickness of face plate of primary members), the thickness $t_b$ (in mm) of tripping brackets is not to be less than (5 + 0.025 $L$), but need not be greater than that of web of primary members, where $L$ being length of ship (which need not be greater than 300 m in calculation). Where the free edge length $l_b$ (in m) is greater than 0.06 $t_b$, the tripping brackets are to have face plate or flange, and the sectional area $A$ (in cm$^2$) of which is generally not to be less than 10 $l_b$.

1.2.5.5 All openings on structural members are to be kept clear of areas of stress concentration and where this is impracticable, corresponding compensation is to be made. All corners of openings are to be well rounded. Where structural members are directly connected with plates, hard points are to be avoided.

1.2.5.6 Within 0.4 $L$ amidships, where the web height of strength deck girders is greater than 65 $t\sqrt{K}$ ($t$ being web thickness, while $K$ being material factor), horizontal stiffeners are to be provided parallel to face plate.

### 1.2.6 Secondary member end connections

1.2.6.1 Unless otherwise specified in this PART, the end connections of secondary members are to comply with the requirements of 1.2.6.

1.2.6.2 The ends of secondary members are generally to be bracketed, see Figure 1.2.6.2. Where secondary members pass through primary members, secondary members are to be connected to the webs of primary members by welding.

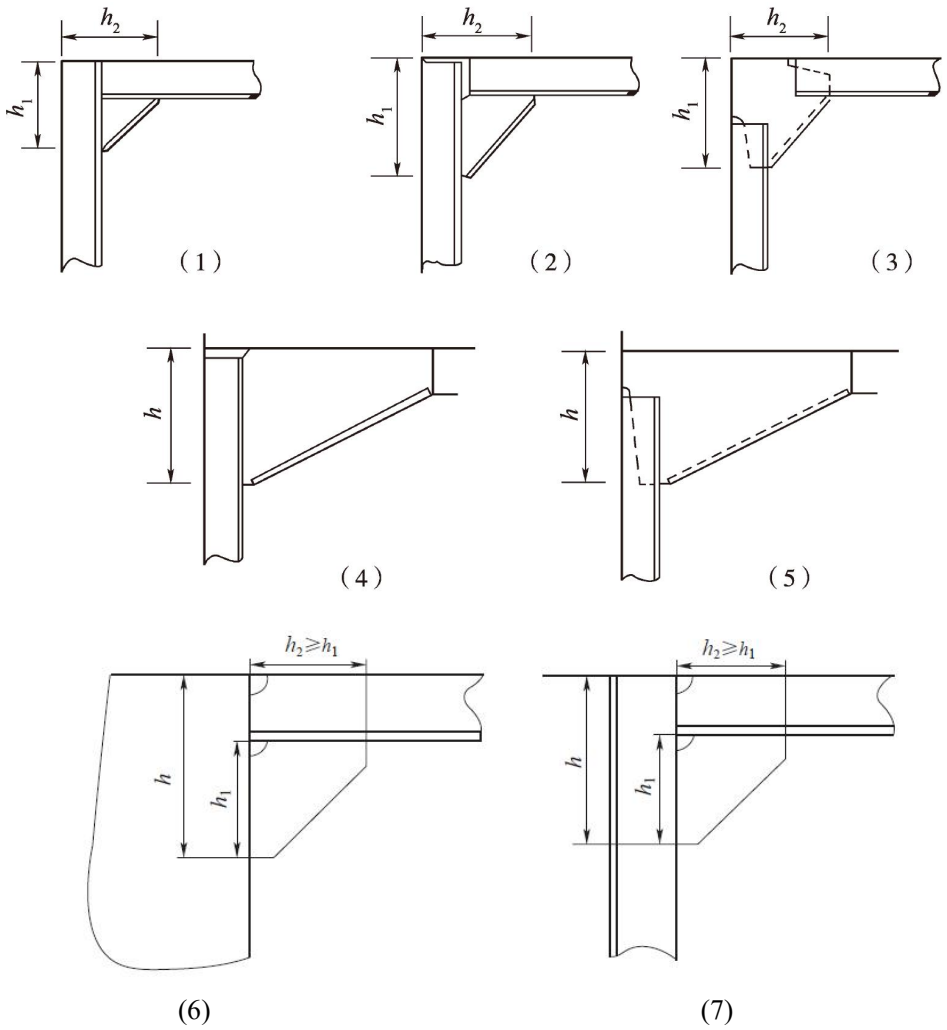



**Figure 1.2.6.2**

1.2.6.3 Where the secondary members contributing to longitudinal bending strength are cut in way of bulkheads or transverse primary members, connecting brackets are to be provided so as to ensure the longitudinal continuity. The brackets at both sides of the bulkheads or transverse primary members are to be in alignment.

1.2.6.4 The section modulus $W$ of frames that is used for determining the scantlings of brackets is to be selected as follows:

(1) For the brackets connecting the secondary to the primary members, $W$ is the section modulus of the secondary members.

(2) For the brackets at frame ends, $W$ is the section modulus of the frames.

(3) For other brackets, $W$ is the lesser of section moduli of two connecting members.

1.2.6.5 The thickness $t$ of brackets is to be not less than that obtained from the following formulae:

$$t = (0.25\sqrt{W} + 2)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \quad \text{mm, for brackets with face plate or flanged brackets}$$

$$t = (0.25\sqrt{W} + 3.5)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \quad \text{mm, for brackets without face plate or unflanged brackets}$$

where: $W$ — Rule section modulus of frames, in $cm^3$;

$R_{eH_s}$ — yield stress of material of frames, in $N/mm^2$;

$R_{eH_b}$ — yield stress of material of brackets, in $N/mm^2$;

$C$ — coefficient, taken as 2.5 for brackets in tanks or 1.5 for other brackets.

The minimum thickness of brackets is generally to be 6.5 mm and need not be greater than 15 mm.

1.2.6.6 Where the Rule section modulus $W$ of frames is not less than 500 $cm^3$ or the free edge is more than 50 times the thickness of brackets in length, the brackets are to be flanged or fitted with face plates. The breadth $b$ of the flanges or face plates is not to be less than that obtained from the following formula:

$$b = 0.04W + 40 \text{ mm, and not less than 50 mm}$$

where: $W$ — Rule section modulus of frames, in $cm^3$.

1.2.6.7 The arm length $h$ of brackets is not to be less than 2.2 times the web depth of frames (where the ends of frames are welded, it may be reduced to not less than twice the web depth, see Figure 1.2.6.2 (1)), and is not to be less than that obtained from the following formula:

$$h = 75\sqrt{\frac{W}{t - C}} \quad \text{mm}$$

where: $W$ — Rule section modulus of frames, in $cm^3$;

$t$ — thickness of brackets, in mm;

$C$ — coefficient, see 1.2.6.5 of this Section.

1.2.6.8 The two arms of the brackets are to be as far as possible equal in length. Where the two arms are not the same in length, they are to comply with the following:

$$h_1 + h_2 \geq 2h$$

$$h_1 \geq 0.8h$$

$$h_2 \geq 0.8h$$

where: $h_1$, $h_2$ — actual length of bracket arms, in mm, as shown in Figure 1.2.6.2;

$h$ — arm length of brackets, in mm, see 1.2.6.7 of this Section.

1.2.6.9 Where the frame is lapped to the bracket, the length of overlap is not to be less than 1.25 times the web depth of the frame.

1.2.6.10 Where the frames are bracketed to primary members, such brackets are in general to be extended to the face plates of primary members.

### 1.2.7 Primary member end connections

1.2.7.1 Unless otherwise specified in this PART, the end connections of primary members are to be in compliance with the requirements of 1.2.7.

1.2.7.2 The ends of primary members are to be fitted with connecting brackets. Where two primary members are connected with a bracket, the scantlings of the bracket may be determined based upon the primary member having the lesser section modulus.

1.2.7.3 The arm length of the end bracket, which includes the web depth of the primary member, is not to be less than twice the web depth of the primary member, and the thickness of the bracket is not to be less than that of the web plate of the primary member. The brackets are to be flanged or fitted with face plates, the scantlings of which are generally to be the same as the face plates of primary members. The web plates of primary members are to be welded to connecting members. Where the side length of the non-stiffened triangle of the bracket is greater than $100t$ ($t$ being the web thickness of the bracket), stiffeners parallel to the face plate of the bracket are to be fitted in accordance with 5.12.2.6 of Chapter 5 of this PART.

1.2.7.4 Where primary members, which are not in tanks, are connected by integral end brackets to bulkheads (i.e. the web plates of primary members gradually raised at ends), the arm length of brackets is not to be less than 1.5 times the web depth of primary members. The web plates of primary members are to be welded to bulkheads and the face plates are to be extended continuously to the bulkheads.

1.2.7.5 Where the deck girders or transverses are to be connected to bulkheads or vertical members of shell plating, the increase of scantlings of the vertical members may be required in order to ensure that connecting joints have adequate resistance to rotation.

1.2.7.6 In order to avoid the stress concentration at ends of primary strength members, the thickness of their web plates are to be adequately increased in way of toe ends of large brackets, and the face plates of brackets are to be beveled to ends. The height of toes is in general not to be greater than the thickness $t_w$ of bracket toes, and is not to be less than 15 mm. For the recommended structural configuration of toe ends of large brackets, see Figure 1.2.7.6.

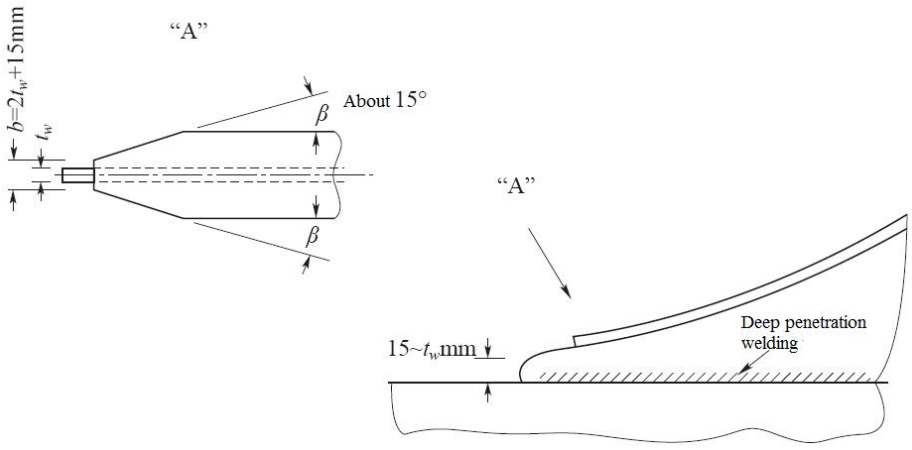



**Figure 1.2.7.6**

### 1.2.8 Standard spacing of framing members

1.2.8.1 The standard spacing $s_b$ of frames, beams or longitudinals (bottom, side and deck) is to be calculated by the following formula:

$$s_b = 0.0016L + 0.5 \quad \text{m, but not greater than 0.7 m}$$

where: $L$ — length of ship, in m.

1.2.8.2 In fore and aft peak tanks, the standard spacing $s_b$ of frames or side longitudinals is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

1.2.8.3 Within 0.05$L$ at ends, the standard spacing $s_b$ of deck longitudinals or deck transverses of superstructures and deckhouses is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

# Section 3 MATERIALS

### 1.3.1 General requirements

1.3.1.1 The chemical composition and mechanical properties of hull structural steels are to comply with the relevant requirements of Chapter 3 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.2 Manufacture and testing of hull structural steels are to comply with the requirements of Chapter 1 and Chapter 2 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.3 Steel castings or steel forgings used for the construction of stems, stern frames, rudder posts, shaft brackets, rudder stocks and other hull structures are to comply with the relevant requirements of Chapter 5 and Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.4 Except where otherwise stated, the elastic modulus of steel is to be taken as $2.06 \times 10^5$ N/mm$^2$.

1.3.1.5 Steels having a yield point not less than 265 N/mm$^2$ are regarded as higher tensile steels.

1.3.1.6 Where higher tensile steel is used for hull structures, its category, grade, location and extent are to be marked on the structural drawings so as to facilitate for maintenance.

1.3.1.7 The material factor $K$ of hull structural steel is given in Table 1.3.1.7.

**Material Factor *K*** **Table 1.3.1.7**

| Yield strength $R_{eH}$ (N/mm$^2$) | Material factor $K$ | Yield strength $R_{eH}$ (N/mm$^2$) | Material factor $K$ |
|---|---|---|---|
| 235 | 1.0 | 355 | 0.72 |
| 265 | 0.92 | 390 | 0.68 (0.66①) |
| 315 | 0.78 | 460 | 0.62② |

Notes:

① only apply to the strength deck and hatch coaming of containerships complying with the requirements of 7.1.1.4 of Section 1, Chapter 7 of this PART;

② only apply to the strength deck, hatch coaming plate and top plating with the range of thickness 50 mm < t ≤ 100 mm onboard container ships.

③ for materials with yield strength not listed in the table, the material factor may be specially considered.

1.3.1.8 Unless specially provided, the yield strength of material (yield stress or yield point of material) is the specified minimum yield stress in the Rules for Materials and Welding, and the

non-proportional extension strength is the minimum value of specified non-proportional extension stress.

### 1.3.2 Requirements for hull structural steel at normal temperature

1.3.2.1 In ships of 90 m or over in length, the hull structural steel is to comply with the requirements of 1.3.2.2 below. For strength members not covered by Tables 1.3.2.2(1) to 1.3.2.2(5) or in ships of less than 90 m in length, grade A/AH steel can generally be used for hull structure. The steel grade is to correspond to the as-built plate thickness and material class.

1.3.2.2 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 1.3.2.2(1) to Table 1.3.2.2(6). General requirements are given in Table 1.3.2.2(1), while additional minimum requirements are given in the following Tables:

Table 1.3.2.2(2): for ships, excluding liquefied gas carriers covered in Table 1.3.2.2(3), with length exceeding 150 m and single strength deck;

Table 1.3.2.2(3): for membrane type liquefied gas carriers with length exceeding 150 m;

Table 1.3.2.2(4): for ships with length exceeding 250 m;

Table 1.3.2.2(5): for ships with ice strengthening.

1.3.2.3 For hull structural members of different material classes, the grades of steel are to be selected from Table 1.3.2.2(6) in accordance with the thickness of the structural members.

1.3.2.4 Where plate thickness is greater than that required in the Rules, the grade of steel is to be selected from Table 1.3.2.2(6) in accordance with the as-built thickness of plates.

1.3.2.5 Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, not to be of lower grades than those corresponding to class II. For rudder and rudder body plates subjected to stress concentrations, e.g. in way of lower support of semi-spade rudders (i.e. rudder horn recess) or at upper part of spade rudders, class III is to be applied.

1.3.2.6 For ships of less than 90 m in length, single strakes required to be of class III within 0.4$L$ amidships are to have breadths not less than 800 + 5$L$ mm ($L$ being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.2.7 The material class used for reinforcement and the quality of materials (i.e. whether mild or higher tensile steel) used for welded attachments, such as backing bars of bilge keels, is generally to be similar to that of the hull envelope plating in way.

Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.

**Material Classes and Grades for Ships in General Table 1.3.2.2(1)**

| Category | Structural member | Material class/grade |
|---|---|---|
| Secondary | (1) Longitudinal bulkhead plating, other than that belonging to the Primary category<br>(2) Deck plating exposed to weather, other than that belonging to the Primary or Special category<br>(3) Side plating | Class I within 0.4$L$ amidships<br>Grade A/AH outside 0.4$L$ amidships |

| | | |
|---|---|---|
| Primary | (1) Bottom plating, including keel plate<br>(2) Strength deck plating, excluding that belonging to the Special category<br>(3) Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings<br>(4) Uppermost strake in longitudinal bulkhead<br>(5) Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank | Class II within 0.4*L* amidships<br>Grade A/AH outside 0.4*L* amidships |
| Special | (1) Sheer strake at strength deck①<br>(2) Stringer plate in strength deck①<br>(3) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships① | Class III within 0.4*L* amidships<br>Class II outside 0.4*L* amidships<br>Class I outside 0.6*L* amidships |
| | (4) Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations | Class III within 0.4*L* amidships<br>Class II outside 0.4*L* amidships<br>Class I outside 0.6*L* amidships<br>Min. Class III within cargo region |
| | (5) Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations<br>(5.1) Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers | Class III within 0.6*L* amidships<br>Class II within rest of cargo region |
| | (6) Bilge strake in ships with double bottom over the full breadth and length less than 150 m | Class II within 0.6*L* amidships<br>Class I outside 0.6*L* amidships |
| | (7) Bilge strake in other ships① | Class III within 0.4*L* amidships<br>Class II outside 0.4*L* amidships<br>Class I outside 0.6*L* amidships |
| | (8) Longitudinal hatch coamings of length greater than 0.15*L* including coaming top plate and flange<br>(9) End brackets and deck house transition of longitudinal cargo hatch coamings | Class III within 0.4*L* amidships<br>Class II outside 0.4*L* amidships<br>Class I outside 0.6*L* amidships<br>Not to be less than Grade D/DH |

Note: ① Single strakes required to be of Class III within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (*L* being the ship's length), need not be greater than 1,800 mm, unless limited by the geometry of the ship's design.

**Minimum Material Grades for Ships with Length Exceeding 150 m and Single Strength Deck**

**Table 1.3.2.2(2)**

| Structural member category | Material grade |
|---|---|
| Longitudinal plating of strength deck where contributing to the longitudinal strength<br>Continuous longitudinal plating of strength members above strength deck | Grade B/AH within 0.4*L* amidships |
| Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck | Grade B/AH within cargo region |

Note: This Table is applicable to ships other than the liquefied gas carriers covered in Table 1.3.2.2(3).

**Minimum Material Grades for Membrane Type Liquefied Gas Carriers with Length Exceeding 150 m①**

**Table 1.3.2.2(3)**

| Structural member category | | Material grade |
|---|---|---|
| Longitudinal plating of strength deck where contributing to the longitudinal strength | | Grade B/AH within 0.4*L* amidships |
| Continuous longitudinal plating of strength members above the strength deck | Trunk deck plating | Class II within 0.4*L* amidships |
| | Inner deck plating<br>Longitudinal strength member plating between the trunk deck and inner deck | Grade B/AH within 0.4*L* amidships |

Note: ① Table 1.3.2.2(3) is applicable to membrane type liquefied gas carriers with deck arrangements as shown in Figure 1.3.2.2. Table 1.3.2.2(3) may apply to similar ship types with a 'double deck' arrangement above the strength deck.

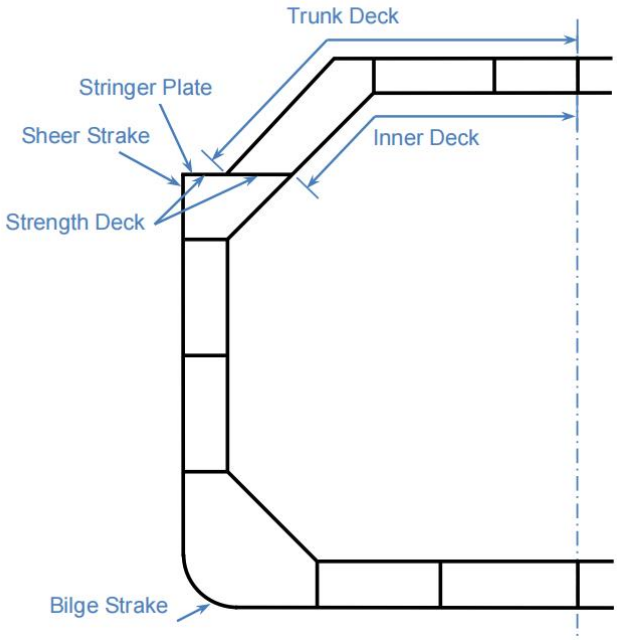



**Figure 1.3.2.2 Typical Deck Arrangement for Membrane Tank Liquefied Gas Carriers**

**Minimum Material Grades for Ships with Length Exceeding 250 m Table 1.3.2.2(4)**

| Structural member category | Material grade |
|---|---|
| Shear strake at strength deck① | Grade E/EH within 0.4*L* amidships |
| Stringer plate in strength deck① | Grade E/EH within 0.4*L* amidships |
| Bilge strake① | Grade D/DH within 0.4*L* amidships |

Note: ① Single strakes required to be of Grade D/DH or Grade E/EH as shown in the above table and within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (*L* being the ship's length), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.

**Minimum Material Grades for Ships with Ice Strengthening Table 1.3.2.2(5)**

| Structural member category | Material grade |
|---|---|
| Shell strakes in way of ice strengthening area for plates | Grade B/AH |

**Steel grade requirements for Material Classes Table 1.3.2.2(6)**

| Material class | I | | II | | III | |
|---|---|---|---|---|---|---|
| Thickness (mm) | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel |
| $t \leq 15$ | A | AH | A | AH | A | AH |
| $15 < t \leq 20$ | A | AH | A | AH | B | AH |
| $20 < t \leq 25$ | A | AH | B | AH | D | DH |
| $25 < t \leq 30$ | A | AH | D | DH | D | DH |
| $30 < t \leq 35$ | B | AH | D | DH | E | EH |
| $35 < t \leq 40$ | B | AH | D | DH | E | EH |
| $40 < t \leq 50$ | D | DH | E | EH | E | EH |

1.3.2.8 The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4 *L* amidships is also to be applied at the poop front and at the ends of the bridge.

1.3.2.9 In the case of container ships, the material class for strength deck, sheer strake and torsion box structure within 0.4 *L* amidships is also to be applied in way of the entire cargo area.

1.3.2.10 On tankers having a poop, the quality of strength deck plating extending forward of the poop to any pump room openings is to be kept unchanged.

1.3.2.11 For hull structures having T connections or cruciform connections, with full penetration welding, and plate material of which is subject to high tensile stress through thickness, the use of Z-direction steel plates having through thickness properties is recommended.

### 1.3.3 Requirements for steel used for refrigerated space structures

1.3.3.1 Where the minimum design temperature $t_D$ of the steel falls below 0℃ in refrigerated spaces, in addition to the requirements of 1.3.2 of this Section, the steel grade for the deck plating, webs of deck girders, longitudinal bulkhead strakes attached to deck and beams for supporting hatchway covers and their face plates is to comply with the requirements of Table 1.3.3.1.

**Steel Grade of Structural Members in Refrigerated Spaces** **Table 1.3.3.1**

| Thickness (mm) | -10℃≤$t_D$<0℃ | | -25℃≤$t_D$<-10℃ | | -40℃≤$t_D$<-25℃ | |
|---|---|---|---|---|---|---|
| | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel |
| $t \leq 12.5$ | B | AH | D | DH | E | EH |
| $12.5 < t \leq 25.5$ | D | DH | E | EH | Specially considered① | Specially considered② |
| $t > 25.5$ | E | EH | Specially considered① | Specially considered② | Specially considered① | Specially considered② |

Notes: ① Austenitic stainless steel may generally be used.

② Grade FH may generally be used.

1.3.3.2 The minimum design temperature of the refrigerated space deck may be assessed by a temperature gradient calculation or may be determined in accordance with Table 1.3.3.2. Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5℃.

**Minimum Design Temperature of Refrigerated Space Deck** **Table 1.3.3.2**

| Item | Arrangement | Deck temperature |
|---|---|---|
| 1 | Deck not covered with insulation in the refrigerated space | Temperature of the refrigerated space |
| 2 | Deck covered with insulation in the refrigerated space and not insulated on the other side | Temperature of the space on the uninsulated side |
| 3 | Deck covered with insulation on both sides:<br>(1) Temperature difference not greater than 11℃<br>(2) Temperature difference greater than 11℃ but not greater than 33℃ | <br>Mean of the temperatures of the spaces above and below the deck<br>Mean of the temperatures of the spaces above and below the deck less 3℃ |

### 1.3.4 Ships exposed to low air temperatures

1.3.4.1 For ships intended to operate for regular service in areas with low air temperatures (below -10℃) during winter seasons, the materials in exposed structures are to be selected based on the design temperature $t_D$. The design temperature $t_D$ is to be taken as defined in 1.3.4.6.

1.3.4.2 Materials in the various strength members above the lowest ballast waterline (BWL) exposed to low air temperatures (including the plating covered by note ⑤ of Table 1.3.4.2) and materials of cargo tank boundary plating to which 1.3.4.7 is applicable are not to be lower than those as given in Table 1.3.4.2. For non-exposed hull structural steel above BWL (except for ⑤ as indicated in Table 1.3.4.2) and hull structural steel below BWL, the requirements in 1.3.2 of this Section apply.

1.3.4.3 Grades of steel for hull structural members of different material classes are to be selected according to Table 1.3.4.3 depending on plate thickness and design temperature. Where the design temperature $t_D$ is below -55℃, the grades of steel are to be subject to special consideration by CCS.

1.3.4.4 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than 800 + 5$L$ mm ($L$ being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.4.5 Plating materials for stern frames, rudders, rudder horns and shaft brackets are not to be of lower grades than those required in 1.3.2 of this Section.

**Material Classes at Low Temperatures** **Table 1.3.4.2**

| Structural member category | Structural member | Material class | |
|---|---|---|---|
| | | Within 0.4$L$ amidships | Outside 0.4$L$ amidships |
| Secondary | Deck plating exposed to weather in general,<br>side plating above BWL,<br>transverse bulkheads above BWL⑤<br>Cargo tank boundary plating exposed to cold cargo⑥ | I | I |
| Primary | Strength deck plating①<br>Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings<br>Longitudinal bulkhead above BWL⑤<br>Top wing tank bulkhead above BWL⑤ | II | I |
| Special | Sheer strake at strength deck, including rounded gunwale②<br>Stringer plate in strength deck②<br>Deck strake at longitudinal bulkhead③<br>Continuous longitudinal hatch coamings④ | III | II |

Notes: ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

② Not to be less than grade E/EH within 0.4 $L$ amidships in ships with length exceeding 250 m.

③ In ships with breadth exceeding 70 m at least three deck strakes to be class III.

④ Not to be less than grade D/DH.

⑤ Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered in the same way as exposed plating and the strake width is to be at least 600 mm.

⑥ For cargo tank boundary plating exposed to cold cargo for ships other than liquefied gas carriers, the requirements of 1.3.4.7 are to be satisfied.

**Material Grade Requirements for Classes I, II and III at Low Temperatures Table 1.3.4.3**

| Class I | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plate thickness, in mm | -11～-15℃ | | -16～-25℃ | | -26～-35℃ | | -36～-45℃ | | -46～-55℃ | |
| | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel |
| $t$≤10 | A | AH | A | AH | B | AH | D | DH | D | DH |
| 10＜$t$≤15 | A | AH | B | AH | D | DH | D | DH | D | DH |
| 15＜$t$≤20 | A | AH | B | AH | D | DH | D | DH | E | EH |
| 20＜$t$≤25 | B | AH | D | DH | D | DH | D | DH | E | EH |
| 25＜$t$≤30 | B | AH | D | DH | D | DH | E | EH | E | EH |
| 30＜$t$≤35 | D | DH | D | DH | D | DH | E | EH | E | EH |
| 35＜$t$≤45 | D | DH | D | DH | E | EH | E | EH | – | FH |
| 45＜$t$≤50 | D | DH | E | EH | E | EH | – | FH | – | FH |
| Class II | | | | | | | | | | |
| Plate thickness, in | -11～-15℃ | | -16～-25℃ | | -26～-35℃ | | -36～-45℃ | | -46～-55℃ | |

| mm | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel |
|---|---|---|---|---|---|---|---|---|---|---|
| $t \leq 10$ | A | AH | B | AH | D | DH | D | DH | E | EH |
| $10 < t \leq 20$ | B | AH | D | DH | D | DH | E | EH | E | EH |
| $20 < t \leq 30$ | D | DH | D | DH | E | EH | E | EH | – | FH |
| $30 < t \leq 40$ | D | DH | E | EH | E | EH | – | FH | – | FH |
| $40 < t \leq 45$ | E | EH | E | EH | – | FH | – | FH | – | – |
| $45 < t \leq 50$ | E | EH | E | EH | – | FH | – | FH | – | – |
| Class III | | | | | | | | | | |
| Plate thickness, in mm | -11～-15℃ | | -16～-25℃ | | -26～-35℃ | | -36～-45℃ | | -46～-55℃ | |
| | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel | Mild steel | Higher tensile steel |
| $t \leq 10$ | B | AH | D | DH | D | DH | E | EH | E | EH |
| $10 < t \leq 20$ | D | DH | D | DH | E | EH | E | EH | – | FH |
| $20 < t \leq 25$ | D | DH | E | EH | E | EH | E | FH | – | FH |
| $25 < t \leq 30$ | D | DH | E | EH | E | EH | – | FH | – | FH |
| $30 < t \leq 35$ | E | EH | E | EH | – | FH | – | FH | – | – |
| $35 < t \leq 40$ | E | EH | E | EH | – | FH | – | FH | – | – |
| $40 < t \leq 50$ | E | EH | – | FH | – | FH | – | – | – | – |

Note: "–" in the Table = Not applicable.

1.3.4.6 The design temperature $t_D$ is to be taken as the lowest mean daily average air temperature in the area of operation, where:

mean: statistical mean over observation period;

daily average: average during one day and night;

lowest: lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

Figure 1.3.4.6 illustrates the temperature definition.

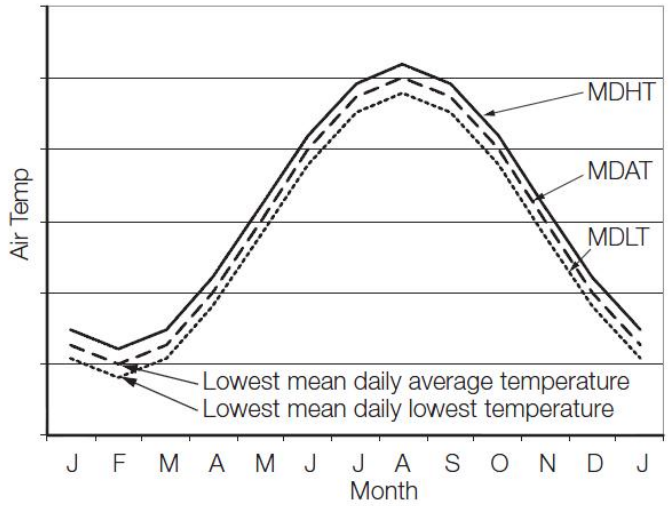



**Figure 1.3.4.6 General Temperature Definitions**

### 1.3.4.7 Cold cargo for ships other than liquefied gas carriers

For ships other than liquefied gas carriers, intended to be loaded with liquid cargo having a temperature below -10℃, e.g. loading from cold onshore storage tanks during winter conditions,

the material grade of cargo tank boundary plating is defined in Table 1.3.4.3 based on the following:

(1) $t_c$ design minimum cargo temperature in ℃;

(2) steel grade corresponding to Class I as given in Table 1.3.4.2.

The design minimum cargo temperature, $t_c$ is to be specified in the loading manual.

### 1.3.5 Use of aluminium alloy

1.3.5.1 The use of aluminum alloy is permitted for superstructures, deckhouses, hatch covers, or other similar structures, based on equivalent strength, instead of hull structural steel as required in the Rules. The chemical composition and mechanical properties of aluminum alloys used are to comply with the relevant requirements of Chapter 8, PART ONE of CCS Rules for Materials and Welding.

1.3.5.2 Unless stated otherwise, the modulus of elasticity of aluminium alloy may be taken as 70,000 N/mm².

1.3.5.3 The scantlings of aluminium alloy structures may be obtained from the following formulae:

For plating thickness: $t_a = t_s \sqrt{K_a}$ mm

For section modulus: $W_a = W_s K_a$ cm$^3$

where:

$t_s$ — thickness of mild steel plating as required in the Rules, in mm;

$W_s$ — section modulus of mild steel as required in the Rules, in cm$^3$;

$K_a$ — material factor for aluminium alloy, $K_a = \frac{235}{R'_{\text{lim}}}$;

$R'_{\text{lim}}$ — the minimum yield stress $R'_{p0.2}$ of parent material which could be guaranteed under welding condition, in N/mm$^2$, to be taken not greater than 70% minimum tensile strength $R'_m$ of parent material which could be guaranteed under welding condition:

$$R'_{p0.2} = \eta_1 R_{p0.2}$$

$$R'_m = \eta_2 R_m;$$

$R_{p0.2}$ — the minimum yield stress of parent material which could be guaranteed under delivery condition, in N/mm$^2$;

$R_m$ — the minimum tensile strength of parent material which could be guaranteed under delivery condition, in N/mm$^2$. $\eta_1$ and $\eta_2$ are given in Table 1.3.5.3(1).

**Aluminium Alloy used for Welded Structures** **Table 1.3.5.3(1)**

| Aluminium alloy | $\eta_1$ | $\eta_2$ |
|---|---|---|
| Not treated by hardening (5000 series under annealed condition O or annealing leveling condition H111) | 1 | 1 |

| | | |
|---|---|---|
| Treated by hardening (5000 series other than O or H111) | $R'_{p0.2}/R_{p0.2}$ | $R'_m/R_m$ |
| Heat treated and hardened (6000 series) (1) | $R'_{p0.2}/R_{p0.2}$ | 0.6 |

Note: (1) If information is not provided, the factor $\eta_1$ is to be taken as metallographic efficiency coefficient $\beta$ defined in Table 1.3.5.3(2);

$R'_{p0.2}$ — the minimum yield stress of material which could be guaranteed under welding condition, in N/mm$^2$;

$R'_m$ — the minimum tensile strength of material which could be guaranteed under welding condition, in N/mm$^2$.

**Alunimun Alloy — Metallographic Efficiency Coefficient $\beta$ Table 1.3.5.3(2)**

| Aluminium alloy | Tempering condition | Total thickness (mm) | $\beta$ |
|---|---|---|---|
| 6005A (opening section) | T5 or T6 | $t \le 6$ | 0.45 |
| | | $t > 6$ | 0.40 |
| 6005A (closed section) | T5 or T6 | All | 0.50 |
| 6061 (section) | T6 | All | 0.53 |
| 6082 (section) | T6 | All | 0.45 |

1.3.5.4 The welding procedures for aluminium alloy are to be subject to approval. The methods used for connecting aluminium alloy with steel members and the information for measures to be taken for corrosion control are to be submitted for examination.

### 1.3.6 Use of stainless steel

1.3.6.1 Stainless steel may be used for tanks onboard oil tankers and chemical tankers to equivalently substitute the hull structure steels required in the Rules.

1.3.6.2 Except where otherwise stated, the elastic modulus of stainless steel may be taken as $2.06\times10^5$ N/mm$^2$.

1.3.6.3 The material factor $K$ is to be calculated by the following formula:

$$K=\frac{235}{R_{eHT}}$$

where: $R_{eHT}$ — the minimum yield strength or non-proportional extension strength of stainless steel under the designed allowable maximum cargo temperature, in N/mm$^2$, to be calculated by the following formulae:

for no nitrogen austenitic stainless steel:

$$R_{eHT}=-40\ln(T)+127+R_{P0.2};$$

for nitrogen austenitic stainless steel:

$$R_{eHT}=-48\ln(T)+142+R_{P0.2};$$

for duplex stainless steel:

$$R_{eHT} = -65\ln(T) + 200 + R_{P0.2}\,.$$

$T$ — the designed allowable maximum cargo temperature, in℃;

$R_{p0.2}$ — the minimum yield strength or non-proportional extension strength of stainless steel, in N/mm$^2$ at room temperature, in accordance with the relevant requirements of Section 8, Chapter 3, PART ONE of CCS Rules for Materials and Welding.

For duplex stainless steel, $K$ is not to be less than 0.68.

# Section 4 WELD DESIGN FOR HULL STRUCTURES

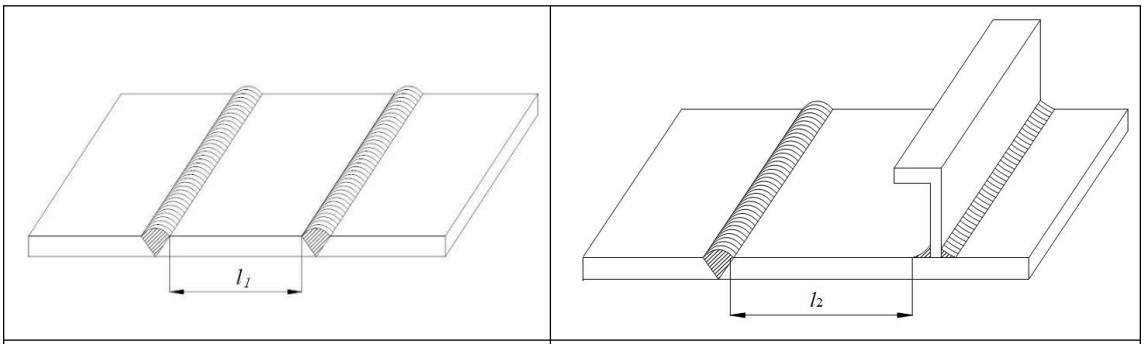
### 1.4.1 General requirements

1.4.1.1 This Section applies to the weld design for normal hull structures and components. Welding procedures for the construction of hull are to comply with the relevant requirements of CCS Rules for Materials and Welding.

1.4.1.2 The arrangement of welds in hull structures is to be such as to allow adequate access for completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of flat (downhand) welding wherever possible.

1.4.1.3 Where welding is used for hull structures, care is to be taken to avoid the arrangement of welded joints in positions of stress concentration. Adequate transition is to be made in way of the abrupt changes of shape or section, and excessive concentration of welds over such positions is to be avoided.

1.4.1.4 Parallel welded seams in the main hull structures are to be spaced an adequate distance apart. The distance $l_1$ between two parallel butt welded seams is not to be less than 100 mm, and the butt welded seams are not to be intersected with an acute angle. Where a butt welded seam is in parallel with a fillet welded seam, the distance $l_2$ between them is not to be less than 10 mm. The distance between the above two welded seams is in general the distance between inner edges of two weld toes (as shown in Figure 1.4.1.4).




| Distance between butt weld toes | Distance between butt and fillet weld toes |
|---|---|

**Figure 1.4.1.4 Distance between parallel welded seams**

1.4.1.5 The shell plating, deck plating, inner bottom plating and bulkhead plating are all to be connected by butt welds.

1.4.1.6 Overlaps are generally not to be used to connect plates in hull structures, particularly for plates which may be subjected to high stress.

1.4.1.7 The use of permanent backing bars in highly stressed welds in hull structures is to be avoided as far as possible.

1.4.1.8 Double continuous fillet welding is to be adopted in the following locations:

(1) boundaries of weathertight decks and erections, including hatch coamings, companionways and coamings of other openings;

(2) boundaries of tanks and watertight compartments;

(3) connections in foundations and supporting structures;

(4) all structure in the aft peak and the aft peak bulkhead stiffeners;

(5) all welding inside tanks intended for chemicals or edible liquid cargoes;

(6) main frames and their upper and lower brackets in cargo holds of bulk carriers to side shell plating and sloped bulkhead plating of topside tanks and hopper side tanks;

(7) all lap welds in tanks;

(8) primary and secondary members to bottom shell in the 0.25 $L$ forward;

(9) centreline girder to keel plate;

(10) boundaries of galleys, pantries, laundry rooms, bathrooms, toilets and storage battery rooms, etc.;

(11) primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections;

(12) other special connections or attachments, and in particular the attachment of minor fittings to higher tensile steel plating, will be specially considered.

1.4.1.9 Where higher tensile steel is used, double continuous fillet welds are normally to be adopted.

1.4.1.10 Details of the welded connections of main structural members of the hull, including type and size of welds, are to be clearly indicated on the plans submitted for approval. The extent to which automatic welding is used is to be indicated on the plans.

1.4.1.11 When arranging side joints of shell plating, the arrangement of longitudinal members such as deck plating, longitudinals and inner bottom margin plates are to be taken into account, avoiding coincidence of the side joints and fillet welds of longitudinal members or their intersection to an excessively small angle. The butt welds of end joint of the shell are to avoid the toes of internal longitudinal members and the fillet welding of transverse members as far as practicable.

### 1.4.2 Welding consumables

1.4.2.1 Welding consumables used for hull structures are to comply with the requirements of CCS Rules for Materials and Welding. The grade of welding consumables selected is to be suitable for the grade of hull structural steel, and is to comply with the requirements of Table 1.4.2.1. Welding consumables of H47 steels are to be selected by referring to CCS Guidelines for Application of Thick Higher Strength Steel Plates for Ships and welding consumables of other steels are to be selected by referring to CCS Guidelines for Inspection of Hull Welds.

**Selection of Welding Consumables** **Table 1.4.2.1**

| Hull structural steel grade / Grade of welding consumables | A | B | D | E | AH27 AH32 AH36 | DH27 DH32 DH36 | EH27 EH32 EH36 | FH27 FH32 FH36 | AH40 | DH40 | EH40 | FH40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | × | | | | | | | | | | | |
| 2 | × | × | × | | | | | | | | | |
| 3 | × | × | × | × | | | | | | | | |
| 1Y | × | | | | ×② | | | | | | | |
| 2Y | × | × | × | | × | × | | | | | | |
| 3Y | × | × | × | × | × | × | × | | | | | |
| 4Y | × | × | × | × | × | × | × | × | | | | |
| 2Y40 | ① | ① | ① | | × | × | | | × | × | | |
| 3Y40 | ① | ① | ① | ① | × | × | × | | × | × | × | |
| 4Y40 | ① | ① | ① | ① | × | × | × | × | × | × | × | × |
| 5Y40 | ① | ① | ① | ① | × | × | × | × | × | × | × | × |

Notes: "×" means applicable;

① When joining structural steels of normal strength, it is not recommended to use a much higher grade of welding consumable.

② When using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.4.2.2 For the joining of steels of different strength levels, the welding consumables in general may be of a type suitable for the lower strength level except at structural discontinuities or areas of stress concentration. For the joining of steels of the same strength level but of different toughness grades, the welding consumables in general may be of a type suitable for the lower toughness grade except for the structural members subjected to complicated forces or severe construction conditions.

1.4.2.3 Low hydrogen welding consumables are to be used for the welding of the following structural members and components:

(1) Circumferential butt welds in the joining of block sections and butt welds of girders;

(2) End and side joints of the shell of ships with ice strengthening;

(3) Masts, derricks, boat davits, bollards and other outfits subjected to heavy loads and all other highly stressed fittings;

(4) Components for which high rigidity is required, such as stems, stern frames, propeller shaft brackets, and joints between them and the shell plating and the hull framing;

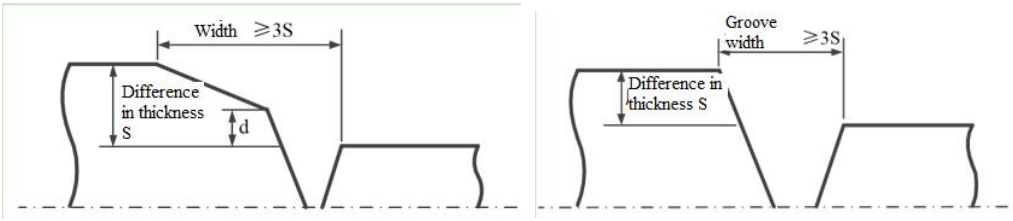
(5) Main engine seatings and the associated structural members.

1.4.2.4 It is recommended that low hydrogen welding consumables be used for the joining of higher strength structural steel or of steel with carbon equivalent over 0.41%.

### 1.4.3 Butt, lap and slot welds

1.4.3.1 Where plates of different thicknesses are to be butt welded and the difference in thickness of one side is less than or equal to 4 mm, the transition may be achieved within the width of the weld. Where the difference in thickness of one side is greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition with the weld. The width is not to be less than 3 times the difference in thickness of one side, and the difference in height of

the two sides of the groove d is not to be greater than 4 mm, as shown in Figure 1.4.3.1(1). Where the groove width is not less than 3 times the difference in thickness of one side, taper may not be necessary and the transition may be achieved within the width of the weld, as shown in Figure 1.4.3.1(2).




(1) (2)

**Figure 1.4.3.1 Butt welding of steel plates of different thickness**

1.4.3.2 Overlaps are generally not to be used to connect plates which may be subjected to high tensile stress or compressive loading. Where plate overlaps are adopted, the breadth (*b*) of the overlap is not to exceed four times nor be less than three times the thickness of the thinner plate, see Figure 1.4.3.2. The joints are to be positioned as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

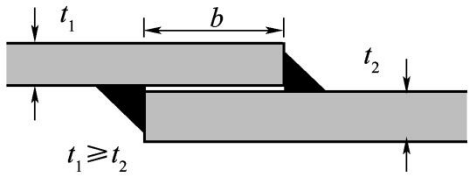



**Figure 1.4.3.2**

1.4.3.3 For the connection of plating to internal webs, where access for fillet welding is not practicable, the closing plating is to be attached by continuous full penetration welds or slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 75 mm and a minimum width of twice the plating thickness, with well rounded ends, and spaced not more than 150 mm apart. Slots are normally not to be filled with welding.

### 1.4.4 Fillet welds

1.4.4.1 T-connections of hull structures are generally to be made by fillet welds on both sides of the abutting plate, including fillet welds, partial penetration fillet welds and full penetration fillet welds. The types and application of fillet welds are to be as shown in Table 1.4.4.1.

1.4.4.2 The size of fillet welds for hull structural connection is to be determined as follows:

(1) The throat thickness *h* of fillet welds is to be determined from the following formula:

$$h = w_\tau t_p \frac{d}{l} \quad \text{mm}$$

where: $t_p$ — thickness of the thinner plate of the abutting plates, in mm, e.g. $t_1$ or $t_2$ in item 1 of Table 1.4.4.1 of this Section, whichever is the lesser;

$d$ — distance between weld fillets, in mm, i.e. the distance between start positions of successive weld fillets for intermittent welding, as shown in items Figure 1.4.4.2 of this Section; where the fillet weld is continuous, $d$ is to be equal to $l$;

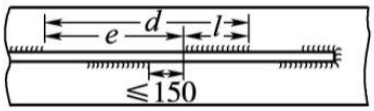
$l$ — the length of weld fillet, in mm, clear of end craters, and is not to be less than 75 mm;

$w_\tau$ — weld factor. The weld factors used for hull structures are as specified in Table 1.4.4.2 of this Section. Where an approved automatic deep penetration procedure is used, $W_\tau$ may be 85% of the value given in the Table.

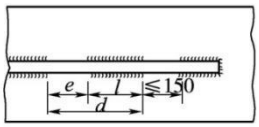
The fillet leg length $K$ is not to be less than the value obtained from the following formula:

$$K = \sqrt{2}h \quad \text{mm}$$

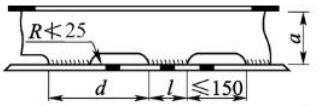
(2) In case of full penetration welding, there is no requirement for root face. For partial penetration welds the root face, f, is, to be taken between 3 mm and 1/3t. The groove angle made to ensure welding bead penetrating up to the root of the groove, α, is usually from 40° to 60°. The welding bead of the full/partial penetration welds is to cover root of the groove.




Staggered intermittent fillet welds




Chain intermittent fillet welds



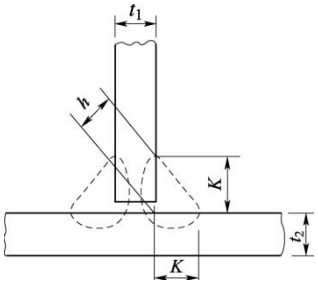
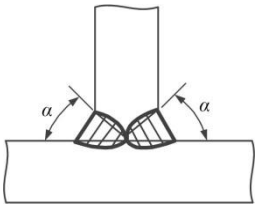
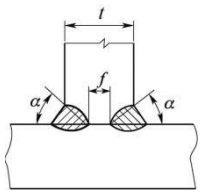
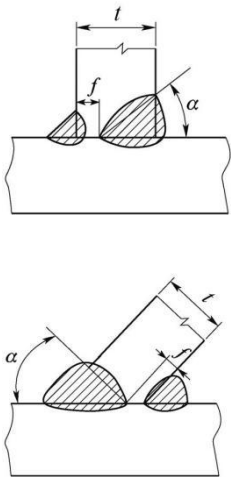

Depth of scallop ≥ 0.25$a$ or 75 mm, whichever is the lesser

Scalloped welding

$l$ – length of weld, $e$ – spacing of welds, $d$ – distance between weld fillets, welding to be carried round both ends of plating for intermittent fillet welds and ends of all lugs for scalloped construction.

**Figure 1.4.4.2**

**Types of Fillet Welds** **Table 1.4.4.1**

| Item | Fillet weld | Type | Remark |
|---|---|---|---|
| 1 | Double continuous |  | Used for ordinary connection<br>$K$ – leg length<br>$h$ – throat thickness<br>$t_1$, $t_2$ – thickness of plates |
| 2 | Double full penetration welding |  | Used in areas with high tensile stresses or areas considered critical<br>$\alpha$ — groove angle |
| 3 | Double symmetrical groove partial penetration welding |  | Used in areas with relatively high tensile stresses or areas considered critical<br>$t$ —thickness of weldment<br>$f$—root face<br>$\alpha$ —groove angle |
| 4 | Double asymmetrical groove partial penetration welding |  | Used in areas with relatively high tensile stresses or areas considered critical<br>$t$ —thickness of weldment<br>$f$—root face<br>$\alpha$ —groove angle |

**Weld Factors** **Table 1.4.4.2**

| Item | Weld factor | Remark |
|---|---|---|
| 1. General application (except as required below): | | |
| Watertight or oiltight plate boundaries | 0.34 | |
| Non-tight plate boundaries | 0.13 | |
| | 0.10 | |
| Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating | 0.13 | In tanks |
| | 0.21 | In way of end connections |
| Panel stiffeners (i.e. small stiffeners) | 0.10 | |
| Overlap welds | 0.27 | |
| Longitudinals of the flat-bar type to plating | 0.21 | Double continuous |
| 2. Bottom construction in way of holds or tanks | | |
| (1) Tight centre girder: to keel | 0.44 | |
| to inner bottom | 0.44 | |
| (2) Non-tight centre girder (or centre keelson): | | |
| to keel | 0.27 | |
| to inner bottom (or face plate of centre keelson) | 0.21 | No scallops |
| (3) Tight boundaries of floors, girders | 0.39 | |
| (4) Non-tight boundaries of floors, girders (or side keelson) and brackets | 0.16 | |
| | 0.21 | In way of 0.2 × span at ends |
| | 0.27 | In way of brackets at lower end of main frame |
| (5) Inner bottom longitudinals or reverse frames to inner bottom | 0.13 | Under holds strengthened for heavy cargoes |
| (6) Floors supporting plane, corrugated, double plate bulkheads and bulkhead stools to inner bottom | 0.44 | Double continuous |
| 3. Hull framing | | |
| (1) Webs of web frames and stringers to shell | 0.16 | |
| (2) Webs of web frames and stringers to face plate | 0.13 | |
| (3) Tank side brackets to shell and inner bottom | 0.34 | |
| (4) Main frames of cargo holds in bulk carriers to shell plating | 0.40 | See 8.8.6 in this PART |
| (5) End brackets of main frames of cargo holds in bulk carriers | 0.44 | See 8.8.6 in this PART |
| 4. Decks and supporting structure | | |
| (1) Strength deck plating to shell | 0.44 | See 5.2.5 of PART THREE of CCS Rules for Materials and Welding |
| | | Generally double continuous |
| (2) Other decks to shell and bulkheads (except where forming tank boundaries) | 0.21 | |
| (3) Webs of cantilevers to deck and to shell in way of root bracket | 0.44 | |
| | 0.21 | |
| (4) Webs of cantilevers to face plate | 0.34 | 0.21 in a length of 0.15 span of hatch girders at ends |
| (5) Pillars: end connections | | |
| | 0.44 | |
| end connections (tubular) | 0.21 | |
| (6) Girder web connections and brackets in way of pillar heads and heels | 0.16 | |
| (7) Web plates of hatch girders and deck web beams to deck, their face plates | | |
| 5. Bulkheads and tank construction | | |
| (1) Watertight plane, corrugated, double plate bulkheads to bottom, inner bottom, bilge plating, hopper and topside tanks, decks and face plates of bulkhead stools | 0.44 | |
| (2) Upper and lower bulkhead stool plates to their face plates | 0.44 | Full penetration in way of lower stool |
| (3) Bulkhead stool plates to inner bottom, deck and bilge | 0.44 | |
| (4) Bulkhead plating to side shell | 0.34 | |
| (5) Bulkhead plating to secondary members where acting as pillars | 0.13 | |
| | 0.13 | |
| (6) Non-watertight pillar bulkhead boundaries | 0.10 | |
| (7) Perforated flats and wash bulkhead boundaries | | |
| 6. Structure in cargo tanks of oil tankers | | |
| (1) Bottom longitudinals to shell | 0.21 | For forward of 0.25$L$ |
| (2) Connections between primary structural members | 0.44 | At bottom |
| | 0.34 | At deck |
| (3) Longitudinal oiltight bulkhead boundaries | 0.44 | Throat thickness $h \geq 0.34t$, $t$ being bulkhead thickness, in mm |

| Item | Weld factor | Remark |
|---|---|---|
| (4) Transverse oiltight bulkhead to bottom | 0.44 | Throat thickness $h \geq 0.34t$, $t$ being bulkhead thickness, in mm |
| Transverse oiltight bulkhead to deck, sides and longitudinal bulkhead | 0.34<br>0.21 | |
| (5) Non-tight bulkhead boundaries | 0.34 | Generally |
| (6) Boundaries of non-watertight girders and floors in double bottom | 0.40<br>0.44<br>0.34 | Within 0.2$L$ at ends of ship<br>Under bulkhead stools<br>Generally |
| (7) Frames rings in hopper and topside tanks to shell, deck and sloping (top) plating | 0.34 | Within 0.2$L$ at ends of ship |
| (8) Boundaries of diaphragms or frame rings, side girders in double hull | 0.40<br>0.34 | |
| (9) Between primary structural members in double hull, double bottom, hopper tanks and topside tanks | 0.27 | Generally |
| (10) Longitudinal girders or frame rings to face plates in hopper tanks, topside tanks and double hull | 0.34 | Within 0.2$L$ at ends of ship<br>Generally |
| (11) Web plates of primary structural members in cargo tanks to longitudinal and transverse bulkheads, inner bottom and deck | 0.44<br>0.27 | Within 0.2$L$ at ends of ship |
| (12) Web plates of primary structural members in cargo tanks to face plates | 0.34 | |
| 7. Structure in hoppers of hopper dredgers | | |
| (1) Bulkhead boundary connections | 0.44<br>0.34 | At bottom and bilge<br>At deck and coamings |
| (2) Cross members to longitudinal bulkheads | 0.44 | |
| (3) Pillar end connections | 0.34 | |
| (4) Hopper door hinges of self-unloading ships | 0.44 | Partial penetration |
| 8. Structure in machinery space | | |
| (1) Non-tight centre girder (or centre keelson) to keel and inner bottom (or face plate of centre keelson) | 0.27 | |
| (2) Non-tight floors to centre girder (or centre keelson) in way of engine, thrust and boiler bearers | 0.27 | |
| (3) Non-tight floors and girders (or side keelsons) to shell and inner bottom | 0.21 | |
| (4) Main engine foundation girders to top plate<br>Main engine foundation girders to hull structure<br>Floors to main engine foundation girders<br>Brackets to main engine foundation girders | 0.44<br>0.44<br>0.27<br>0.21 | Partial penetration, girders to be tapered to both sides, root face ≤ 1/3 girder thickness |
| (5) Transverse and longitudinal framing to shell | 0.13 | |
| 9. Construction in 0.25$L$ forward | | |
| (1) Floors and girders (or centre keelson, etc.) to shell and inner bottom | 0.21 | |
| (2) Bottom longitudinals to shell | 0.13 | |
| (3) Transverse and longitudinal side framing to shell | 0.13 | |
| (4) Tank side brackets to frame and inner bottom | 0.34 | |
| (5) Panting stringers to shell and frames | 0.34 | |
| (6) All internal structure in fore peak | 0.13 | Unless a greater weld factor is required |
| 10. Aft peak construction: All internal structure including stiffeners on aft peak bulkhead | 0.21 | Unless a greater weld factor is required |
| 11. Superstructure and deckhouses | | |
| (1) Connection of external bulkheads to deck | 0.34<br>0.21 | 1st and 2nd tier erections<br>Elsewhere |
| (2) Internal bulkheads to deck | 0.13 | |
| 12. Hatchways and closing arrangements | | |
| (1) Hatch coamings to deck | 0.34 | 0.44 at corners |
| (2) Hatch coaming stays (stiffeners, brackets) to coaming<br>to deck | 0.13<br>0.21 | |
| (3) Hatch cover rest bar | 0.16 | |
| (4) Cleats and fittings | 0.44 | Increased welding may be required |
| (5) Primary and secondary stiffening of hatch covers | 0.10 | 0.13 for tank covers and where covers strengthened for loads over |

| Item | Weld factor | Remark |
|---|---|---|
| 13. Steering control systems | | |
| (1) Rudder | | |
| ① Fabricated mainpiece and mainpiece to side plates and webs | 0.44 | |
| | 0.44 | |
| ② Slot welds inside plates | 0.21 | |
| ③ Remaining construction | 0.44 | |
| (2) Fixed and steering nozzles: Main structure | 0.21 | |
| Elsewhere | 0.44 | |
| (3) Thruster units and stabilizers: Main structure | 0.21 | |
| Elsewhere | | |
| 14. Miscellaneous fittings and equipment | | |
| (1) Rings for manhole type covers to deck, inner bottom or bulkhead | 0.34 | |
| | 0.34 | |
| (2) Frames of shell and weathertight bulkhead doors | 0.21 | |
| (3) Stiffening of watertight doors | 0.34 | Positions 1 and 2 specified by Load Line assignment |
| (4) Ventilator, air pipe, etc., coamings to deck | | |
| | 0.21 | |
| Elsewhere | 0.21 | |
| (5) Ventilator, etc., fittings | 0.44 | |
| (6) Scuppers and discharges, to deck | 0.44 | See 5.2.7 of PART THREE of CCS Rules for Materials and Welding |
| (7) Masts, derrick posts, crane pedestals, etc., to deck | | |
| | 0.21 | Special equipment subject to design |
| (8) Deck machinery seats to deck | 0.21 | Increased or full penetration welding may be required |
| (9) Mooring equipment (bollards, etc.) seats to deck | | |
| | 0.21 | |
| (10) Bulwark stays to deck | 0.34 | |
| (11) Bulwark attachment and guard rails, stanchions, etc., to deck | 0.34 | |
| | 0.21 | |
| (12) Bilge keel backing bars to shell | | |
| (13) Bilge keels to backing bars | | |

1.4.4.3 Where the thickness of the abutting member of the T connection (e.g. the web of a stiffener or longitudinal) is greater than 15 mm and exceeds the thickness of the table member (e.g. bulkhead plating, shell plating or deck plating), the welding is to be double continuous and the throat thickness $h$ of the weld is to be neither less than the value given in Table 1.4.4.4(2) of this Section, nor less than the greater of the following:

$$h = 0.5Ct_v \quad \text{mm}$$

$$h = 0.21t_h \quad \text{mm}$$

where: $t_v$ — thickness of the abutting member, in mm;

$t_h$ — thickness of the table member, in mm;

$C$ — coefficient, 0.21 for dry cargo holds, or 0.27 for liquid tanks.

1.4.4.4 Except as permitted by 1.4.4.2 and 1.4.4.3 of this Section, the throat thickness of all fillet welds is to comply with the following requirements:

(1) The limits of throat thickness are to be as shown in Table 1.4.4.4(1);

(2) The minimum value of throat thickness is also to comply with the requirements of Table 1.4.4.4(2).

**Limits of Throat Thickness** **Table 1.4.4.4(1)**

| Item | Limits of throat thickness (mm) |
|---|---|

| | Minimum | Maximum |
|---|---|---|
| Double continuous welding | 0.21 $t_p$ | 0.44 $t_p$ |
| Intermittent welding | 0.27 $t_p$ | 0.44 $t_p$ |

Notes: ① For $t_p$, see 1.4.4.2(1) of this Section.

② When the actual plate thickness $t_p'$ exceeds 25 mm, $t_p = 0.5(t_p' + 25)$.

**Minimum Throat Thickness** **Table 1.4.4.4(2)**

| Plate thickness $t_p$ | | ≤ 7.5 | > 7.5 |
|---|---|---|---|
| Minimum throat thickness (mm) | Manual or automatic welding | 3 | 3.25 |
| | Automatic deep penetration welding | 3 | 3 |

Note: For $t_p$, see 1.4.4.2(1) of this Section.

1.4.4.5 Where intermittent fillet welds are used for the connection of hull members, double continuous fillet welding is to be carried out for a specified length of round-the-end weld in the following locations:

(1) The length of the round-the-end weld at the ends of brackets is not to be less than the depth of the connecting members, nor less than 75 mm.

(2) Where the ends of sections, particularly of short sections, are snipped off, the length of the round-the-end weld is to be not less than the height of such sections or the length of snipping.

(3) Where fillet welding is used in way of brackets, lugs and scallops and at the orthogonal connections with other members, the length of the round-the-end weld is not to be less than 75 mm for plate thickness > 12 mm, and not less than 50 mm for plate thickness ≤ 12 mm.

1.4.4.6 Where scallops are cut in the structural members for intermittent welding, both ends of the scallop are to be rounded and smooth. But no scallops are permitted in the following positions:

(1) in way of the ends of brackets where stress concentration occurs;

(2) in the main frames, longitudinals and stiffeners for a region of at least 230 mm on each side of the intersection with a primary supporting member.

1.4.4.7 Where a structural member passes through a watertight or an oiltight bulkhead, in addition to the fitting of a welded collar on the bulkhead, a small semicircular notch is to be cut on one side of the passing member as shown in Figure 1.4.4.7(1). And double continuous fillet welding is to be carried out round the end of the semicircular notch to the bulkhead so as to ensure tightness of the bulkhead.

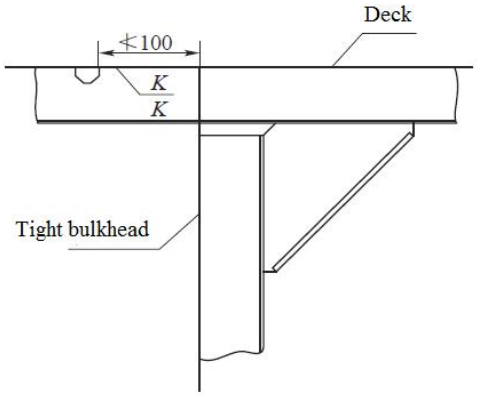



**Figure 1.4.4.7(1)**

For bulkheads adjacent to tanks, fillet welds in way of 150 mm fore and aft of oil/gastight or watertight bulkheads are to be properly beveled and full penetration is required in order to prevent the leakage of dangerous gases or liquids into adjacent compartments, see Figure 1.4.4.7(2). Other equivalent means may also be adopted.

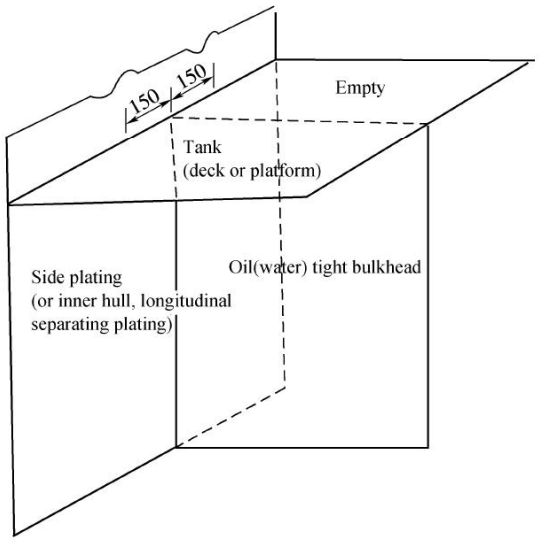



**Figure 1.4.4.7(2)**

1.4.4.8 The size of fillet welds in primary members is to comply with the following:

(1) Weld factors may be obtained from Table 1.4.4.8.

(2) Where the webs of primary members are cut for the passage of secondary members and the width of the notch exceeds 15% of the stiffener spacing, the weld factor $W_\tau$ or the leg length $K$ of fillet weld is to be multiplied by coefficient $C$ obtained from the following formula:

$$C = \frac{0.85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

(3) In calculation of the throat thickness, the overall length of the weld at the ends of the member may be taken into account.

**Weld Factors of Primary Members** **Table 1.4.4.8**

| Cross-sectional area of face plate of T-type members ($cm^2$) | Position① | In tanks | | In dry spaces | |
|---|---|---|---|---|---|
| | | To face plate | To plating | To face plate | To plating |
| | | $w_\tau$ | $w_\tau$ | $w_\tau$ | $w_\tau$ |
| $A \leq 30$ | At ends | 0.21 | 0.27 | 0.21 | 0.21 |
| | Remainder | 0.10 | 0.16 | 0.10 | 0.13 |
| $30 < A \leq 65$ | At ends | 0.21 | 0.34 | 0.21 | 0.21 |
| | Remainder | 0.13 | 0.27 | 0.13 | 0.16 |
| $65 < A \leq 95$ | At ends | 0.34 | 0.44③ | 0.21 | 0.27 |
| | Remainder | 0.27② | 0.34 | 0.16 | 0.21 |
| $95 < A \leq 130$ | At ends | 0.34 | 0.44③ | 0.27 | 0.34 |
| | Remainder | 0.27② | 0.34 | 0.21 | 0.27 |
| A > 130 | At ends | 0.44 | 0.44③ | 0.34 | 0.44③ |
| | Remainder | 0.34 | 0.34 | 0.27 | 0.34 |

Notes: ① The weld factors "at ends" are to be applied for 0.2 × the length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0.3 × length from the bottom. "Length of the member" means the overall length of the member (including the end brackets).

② In cargo oil tanks, the weld factor is to be 0.34. The final throat thickness of the weld fillet is not to be less than 0.34 $t_p$. For $t_p$, see 1.4.4.2(1) of this Section.

③ Where the web plate thickness is increased locally, the throat thickness is to be determined by 0.44 $t_p$ or 0.34 $t_c$, whichever is the greater. For $t_p$, see 1.4.4.2(1) of this Section, and $t_c$ is the increased thickness of plate.

④ In oil tankers over 120 m in length, the weld factors of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads, all in the lower half depth, are not to be less than 0.34.

1.4.4.9 The area of welding of end connections of primary members is not to be less than the cross-sectional area of the member, and the weld factor is not to be less than 0.34 in tanks or 0.27 elsewhere.

1.4.4.10 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area $A_w$ of weld is not to be less than the cross-sectional area of the strength member.

1.4.4.11 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

(1) The area $A_w$ of weld is to be not less than 0.5 $\sqrt{W}$ and the weld factor not less than 0.34 in tanks or 0.27 in dry spaces, where $W$ is the section modulus of the secondary member, in $cm^3$.

(2) In cargo oil tanks, the size of weld is to be increased by 20% above that obtained from (1) above.

1.4.4.12 The fillet welding of secondary member end connections is to be in accordance with Table 1.4.4.12 and where two values are given, the greater is to be taken.

**Weld Factors of End Connections of Secondary Members** **Table 1.4.4.12**

| Connection | Weld area $A_w$ ($cm^2$) | Weld factor $w_\tau$ |
|---|---|---|

| | | |
|---|---|---|
| 1. Stiffener welded direct to deck, shell, bulkhead plating etc. | 0.25 $A_s$ or 6.5 | 0.34 |
| 2. Stiffener to bracket or bracket lapped to stiffener<br>(1) in dry space<br>(2) in tank<br>(3) main frame to tank side bracket in 0.15$L$ forward | | <br>0.27<br>0.34<br>0.34 |
| 3. Bracket welded to face of stiffener and bracket connection to shell, deck, bulkhead plating, etc. | – | 0.34 |
| 4. Stiffener to plating for 0.1 × span at ends where not fixed by welding | – | 0.34 |

Notes: $A_s$ – cross-sectional area of the stiffener, in cm$^2$;
$A_w$ – area of the weld (in cm$^2$), and is calculated as total length of weld (in cm) × throat thickness (in cm).

1.4.4.13 Single-sided continuous fillet welding may be acceptable for dry spaces in deckhouse. Where this is adopted, the fillet leg length K is to be 2 times the value calculated in 1.4.4.2, where $d$ / $l$ is to be taken as 1.

# Section 5 DIRECT STRENGTH CALCULATIONS

### 1.5.1 General requirements

1.5.1.1 Where specifically required in this PART, or a novel structural configuration is adopted, or structural arrangements, ship's proportions and scantlings are not covered by the Rules, direct calculations are to be performed.

1.5.1.2 Except as otherwise specified, this Section in general applies to finite element (FE) analysis of cargo holds and the whole ship.

1.5.1.3 The loading conditions taken into account for direct strength calculations are to include most severe conditions for the design of ships.

1.5.1.4 The as-built thicknesses are to be applied for FE model scantlings, no additional thickness given by the shipowner is to be taken into consideration.

1.5.1.5 Except as otherwise specified, the structural scantlings required by this PART can not be reduced for the direct strength calculation.

1.5.1.6 Suitable general programs may be employed in direct calculations. Where a not generally used program is to be employed, supporting information is also to be submitted to substantiate the validity of the computer program.

1.5.1.7 The service coefficient $f_r$ is to be determined as follows:

For open sea service, $f_r = 1.0$;

For greater coastal service, $f_r = 0.9$;

For coastal service, $f_r = 0.85$;

For sheltered water service $f_r = 0.8$.

1.5.1.8 The following documentation is to be submitted:

(1) list of drawings used;

(2) description of FE calculation progeams used;

(3) detailed description of structrual FE model;

(4) description of physical properties and material properties of structrual model;

(5) detailed description of boundary conditions;

(6) detailed description of loading conditions;

(7) details of applied loads;

(8) figures of the overall and local deformations;

(9) results of yield strength evaluation;

(10) results of buckling strength evaluation;

(11) output showing whether the structure meet design criteria or not.

1.5.1.9 Definitions

(1) A right-handed coordinate system is to be used, see Figure 1.5.1.9, with:

① the X-axis measured in the longitudinal direction, positive forward;

② the Y-axis measured in the transverse direction, positive to port from the centerline;

③ the Z-axis measured in the vertical direction, positive upwards.

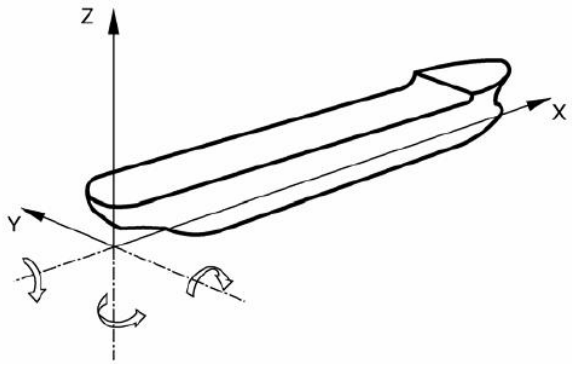



**Figure 1.5.1.9 Coordinate system**

(2) The von Mises stress $\sigma_e$ is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2} \quad \text{N/mm}^2$$

where: $\sigma_x$ — stress of element in direction $x$, in N/mm$^2$;

$\sigma_y$ — stress of element in direction $y$, in N/mm$^2$;

$\tau_{xy}$ — shear stress of element in plane $xy$, in N/mm$^2$.

(3) The shear stress $\tau$, in N/mm$^2$; for the primary structural members along the depth direction, the average shear stress of plate element may be calculated as follows:

$$\tau = \frac{\sum_{i=1}^{n}(\tau_i A_i)}{A_w} \quad \text{N/mm}^2$$

where: $A_i$ — the effective shear area of element $i$, in mm$^2$;

$\tau_i$ — the shear stress of element $i$, in N/mm$^2$;

$A_w$ — the total effective shear area of actual structure, in mm$^2$.

### 1.5.2 Motions and accelerations

1.5.2.1 Ship's absolute motions and accelerations

(1) The roll period $T_R$ of the ship is to be calculated as follows:

$$T_R = 2\frac{k_r}{\sqrt{GM}} \qquad \text{s}$$

where: $k_r$ — roll radius of gyration, in m, to be assumed as follows if no specific values available:

$k_r = 0.35B$ ballast condition for oil tankers;

$k_r = 0.25B$ ore carriers;

$k_r = 0.39B$ others;

where: $B$ — breadth of ship, in m;

$GM$ — initial metacentric height in the condition considered, to be assumed as follows if no specific values available:

$GM = 0.12B$ for tankers and bulk carriers;

$= 0.07B$ for others.

(2) The maximum roll angle $\varphi_m$ is to be calculated as follows, but need not be greater than 0.523 rad:

$$\varphi_m = f_r k \frac{62.5 - 1.25T_R}{B + 75} \qquad \text{rad}$$

where: $T_R$ — calculated as (1);

$B$ — breadth of ship, in m;

$f_r$ — service coefficient, see 1.5.1.7 of this Section;

$k$ — coefficient, to be taken as follows:

$k = 1.2$ for ships without bilge keel;

$k = 1.0$ for ships with bilge keel;

$k = 0.8$ for ships with activated stabilizers.

(3) Pitch period $T_p$ is to be calculated as follows:

$$T_P = 1.80\sqrt{\frac{L}{10}} \qquad \text{s}$$

where: $L$ — length of ship, in m.

(4) The maximum pitch angle $\psi_m$ is to be calculated as follows, but need not be greater than 0.14 rad:

$$\psi_m = 0.25\frac{a_0}{C_b} \qquad \text{rad}$$

where: $C_b$ — block coefficient;

$a_0$ — acceleration factor, to be calculated as follows:

$$a_0 = f_r\left(3\frac{C}{L} + C_V\frac{V}{\sqrt{L}}\right)$$

where: $f_r$ — service coefficient, see 1.5.1.7 of this Section;

$C_V = \frac{\sqrt{L}}{50}$, not to be greater than 0.2;

$V$ — maximum service speed, in kn;

$C$ — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART;

$L$ — length of ship, in m.

1.5.2.2 Ship's relative motions and accelerations

(1) Surging acceleration $a_x$ is to be calculated as follows:

$$a_x = 2a_0\sqrt{C_b} \qquad \text{m/s}^2$$

where: $C_b$ — block coefficient;

$a_0$ — see 1.5.2.1(4) of this Section.

(2) Sway acceleration $a_y$ is to be calculated as follows:

$$a_y = 3a_0 \qquad \text{m/s}^2$$

where: $a_0$ — see 1.5.2.1(4) of this Section.

(3) Heave acceleration $a_z$ is to be calculated as follows:

$$a_z = 7\frac{a_0}{\sqrt{C_b}} \qquad \text{m/s}^2$$

where: $C_b$ — block coefficient;

$a_0$ — see 1.5.2.1(4) of this Section.

(4) Roll acceleration $a_r$ is to be calculated as follows:

$$a_r = \varphi_m\left(\frac{6.28}{T_R}\right)^2 \qquad \text{rad/s}^2$$

where: $T_R$ — roll period, in sec., to be calculated according to 1.5.2.1(1) of this Section;

$\varphi_m$ — maximum roll angle, in rad, to be calculated according to 1.5.2.1(2) of this Section.

(5) Pitch acceleration $a_p$ is to be calculated as follows:

$$a_p = \psi_m\left(\frac{6.28}{T_p}\right)^2 \qquad \text{rad/s}^2$$

where: $T_P$ — pitch period, in sec., to be calculated according to 1.5.2.1(3) of this Section;

$\psi_m$ — maximum pitch angle, in rad, to be calculated according to 1.5.2.1(4) of this Section.

(6) Transverse combined acceleration $a_t$ is to be calculated as follows:

$$a_t = \sqrt{a_y^2 + \left[a_r\left(z - z_{rp}\right) + 10\sin\varphi_m\right]^2} \qquad \text{m/s}^2$$

where: $a_y$ — sway acceleration, see 1.5.2.2(2);

$a_r$ — roll acceleration, see 1.5.2.2(4);

$\varphi_m$ — maximum roll angle, see 1.5.2.1(2) of this Section;

$z$ — vertical distance from the point considered to baseline;

$z_{rp}$ — vertical distance from axis of gyration for roll and that for pitch to baseline, to be taken from the values obtained by the following two formulae, whichever is the lesser;

$$z_{rp1} = \frac{D}{4} + \frac{d_1}{2} \quad \text{m}$$

$$z_{rp2} = \frac{D}{2} \quad \text{m}$$

where:

$D$ — moulded depth, in m;

$d_1$ — draught the condition considered, in m.

(7) Longitudinal combined acceleration $a_l$ is to be obtained by the following formula:

$$a_l = \sqrt{a_x^2 + \left[ a_p \left( z - z_{rp} \right) + 10 \sin \psi_m \right]^2} \quad \text{m/s}^2$$

where: $z_{rp}$, $z$ — see 1.5.2.2 (6);

$a_x$ — surge acceleration, see 1.5.2.2 (1);

$a_p$ — pitch acceleration, see 1.5.2.2 (5);

$\psi_m$ — maximum roll angle, in rad, calculated according to 1.5.2.1 (4) of this Section.

(8) Vertical combined acceleration $a_v$ is to be taken from the values obtained by the following two formulae, whichever is greater:

$$a_{v1} = \sqrt{a_z^2 + a_r^2 y^2} \quad \text{m/s}^2$$

$$a_{v2} = \sqrt{a_z^2 + a_p^2 (x - 0.45L)^2} \quad \text{m/s}^2$$

where: $a_z$ — heave acceleration, see 1.5.2.2 (3);

$a_r$ — roll acceleration, see 1.5.2.2(4);

$a_p$ — pitch acceleration, see 1.5.2.2(5);

$x$ — longitudinal distance from the point considered to AP, in m;

$y$ — transverse distance from the point considered to longitudinal centerline, in m;

$L$ — length of ship, in m.

### 1.5.3 External sea pressure

1.5.3.1 The external sea pressure consists of hydrostatic pressure and hydrodynamic wave pressure.

1.5.3.2 The hydrostatic pressure $P_{hs}$ is to be calculated as follows:

$p_{hs} = \rho_w g (d_1 - z)$ kN/m$^2$ for the considered load point below the waterline;

$= 0$ kN/m$^2$ for the considered load point above the waterline.

where: $\rho_w$ — density of sea water, taken as 1.025 t/m$^3$;

$d_1$ — draught in the considered condition, in m;

$z$ — vertical distance measured from the considered point to the baseline, in m.

1.5.3.3 Hydrodynamic wave pressure

(1) The hydrodynamic wave pressure $p_{WL}$ at the side waterline of the ship is to be calculated by the following formula:

$$p_{WL} = f_r\left(2B^{0.66} + 3CC_b + 0.4d_1\right) \qquad \text{kN/m}^2$$

where: $f_r$ — service coefficient, see 1.5.1.7 of this Section;

$B$ — breadth of ship, in m;

$C_b$ — block coefficient;

$d_1$ — draught under the loading condition for calculation, in m;

$C$ — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART.

(2) The hydrodynamic wave pressure $p_{BS}$ at the bilge of the ship is to be calculated by the following formula:

$$p_{BS} = p_{WL} - 1.2d_1 \qquad \text{kN/m}^2$$

where: $p_{WL}, d_1$ — see 1.5.3.3(1).

(3) The hydrodynamic wave pressure $p_{BC}$ at the bottom centerline is to be calculated by the following formula:

$$p_{BC} = 0.5\left(p_{WL} - 1.2d_1\right) \qquad \text{kN/m}^2$$

where: $p_{WL}, d_1$ — see 1.5.3.3(1).

(4) The hydrodynamic wave pressure $p_{hd}$ at any point below the waterline is to be calculated by the following formula:

$$p_{hd} = p_{WL} + \left(p_{BS} - p_{WL}\right)\left(1 - \frac{z}{d_1}\right) + \left(p_{BC} - p_{BS}\right)\left(1 - \frac{2y}{B}\right) \qquad \text{kN/m}^2$$

where: $p_{WL}$ — calculated according to 1.5.3.3 (1);

$p_{BS}$ — calculated according to 1.5.3.3 (2);

$p_{BC}$ — calculated according to 1.5.3.3 (3);

$B$ — breadth of ship, in m;

$d_1$ — draught in the considered condition, in m;

$y$ — transverse distance measured from the considered point to the centreline, in m;

$z$ — vertical distance measured from the considered point to the baseline, in m.

(5) The hydrodynamic wave pressure $p_{hd}$ at any point at side shell plating above the waterline is to be calculated by the following formulae:

$$p_{hd} = p_{WL} - 10\left(z - d_1\right) \qquad \text{kN/m}^2 \qquad \text{for } d_1 < z \le d_1 + \frac{p_{WL}}{10}$$

$$p_{hd} = 0 \qquad \text{kN/m}^2 \qquad \text{for } d_1 + \frac{p_{WL}}{10} < z$$

where: $p_{WL}$ — calculated according to 1.5.3.3 (1);

$d_1$ — draught under the considered condition, in m;

$z$ — vertical distance measured from the considered point to the baseline, in m.

(6) The green sea load $p_{wdk}$ on weather deck is to be calculated by the following formula, but not less than zero:

$$p_{wdk} = p_{WL} - 10\left(z_{dk} - d_1\right) \qquad \text{kN/m}^2$$

where: $p_{WL}$ — calculated according to 1.5.3.3(1);

$d_1$ — draught under the considered condition, in m;

$z_{dk}$ — vertical distance measured from the weather deck to the baseline, in m.

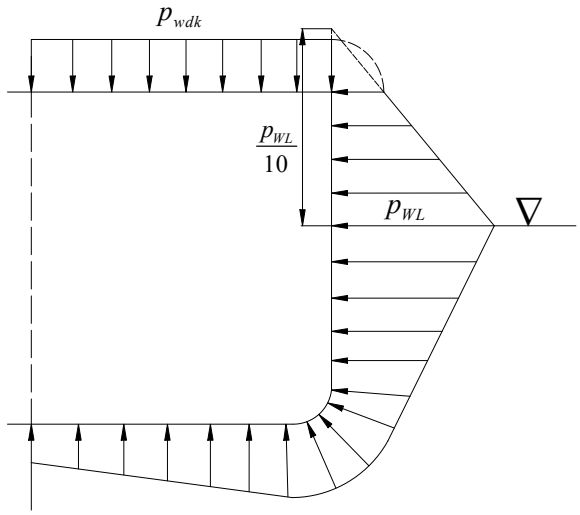



**Figure 1.5.3.3 External Hydrodynamic Wave Pressure**

### 1.5.4 Dry bulk cargo pressure

1.5.4.1 The pressure caused by dry bulk cargo is to be calculated according to 1.5.4.2 and 1.5.4.3.

1.5.4.2 The top surface of dry bulk cargo is to be determined according to the following requirements:

(1) For a prismatic cargo hold where the dry bulk cargo is loaded to the top of the hatch coaming, the top surface of cargo is to be determined equivalently according to the same cargo volume within the cargo hold. The equivalent cargo horizontal surface at $h_C$ above the inner bottom, as shown in Figure 1.5.4.2(1), is to be calculated by the following formula:

$$h_C = h_{HPU} + h_0 \qquad \text{m}$$

where:

$h_{HPU}$ — vertical distance from inner bottom to the lower point of intersection of topside tank with side shell plating or inner hull plating, in m, see Figure 1.5.4.2(1);

$h_0$ — vertical distance from the lower point of intersection of topside tank with side shell plating or inner hull to equivalent cargo horizontal surface, $h_0 = \frac{S_A}{B_H}$, in m;

where:

$$S_A = S_0 + \frac{V_{HC}}{l_H}$$

$S_0$ —shadow area from the lower point of intersection of topside tank with side shell plating or inner hull plating to horizontal surface of upper deck, in $m^2$, see Figure 1.5.4.2(1);

$V_{HC}$ — volume enclosed by hatch coaming from deck to coaming top, in $m^3$;

$l_H$ — length of cargo hold, in m;

$B_H$ — average breadth of cargo hold, in m.

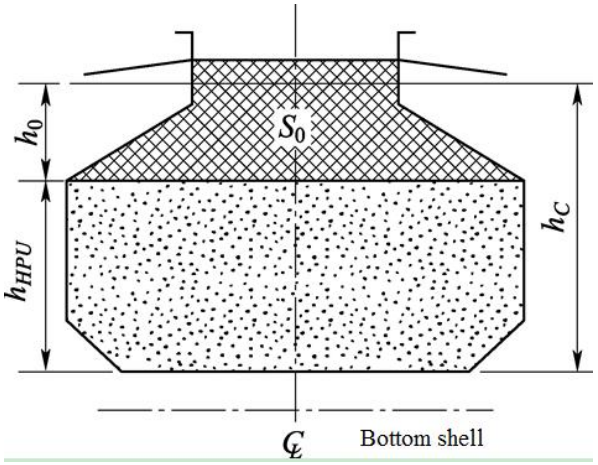



**Figure 1.5.4.2(1) Definitions of $h_c$, $h_0$, $h_{HPU}$ and $S_0$**

(2) For a prismatic cargo hold where the dry bulk cargo is not loaded to upper deck, it is assumed that its top surface is parabolic across along the hull and the shape of each cross section along the length of the cargo hold is the same, as shown in Figure 1.5.4.2(2). Parameters of the top surface shape are to be determined according to cargo volume in the cargo hold (taken as $M/\rho_C$) and calculated as follows:

$h_C = h_y + h_2 + h_{HPL}$ in m, when $h_2 \geq 0$

$h_C = h_y + h_{22}$ in m, when $|y| \leqslant \frac{B_2}{2}$ and $h_2 < 0$

$h_C = 0$ in m, when $|y| > \frac{B_2}{2}$ and $h_2 < 0$

where:

$h_2$ — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_2 = \frac{M}{\rho_C B_H l_H} - \frac{B_H + B_{IB}}{2B_H} h_{HPL} - \frac{B_H}{6}\tan\delta + \frac{V_{TS}}{B_H \cdot l_H}$$

$h_y$ — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_y = h_1(1 - \frac{4y^2}{B_H^2}) \quad \text{if } h_2 \geq 0$$

$$h_y = h_1(1 - \frac{4y^2}{B_2^2}) \quad \text{if } h_2 < 0$$

$B_2$ — cargo surface breadth if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$B_2 = \sqrt{\frac{\frac{6}{l_H}(\frac{M}{\rho_C} + V_{TS}) + \frac{3B_{IB}^2}{B_H - B_{IB}} h_{HPL}}{\tan\delta + \frac{3h_{HPL}}{B_H - B_{IB}}}}$$

$h_{22}$ — distance if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_{22} = h_{HPL}(\frac{B_2 - B_{IB}}{B_H - B_{IB}})$$

$h_{HPL}$ — vertical distance from inner bottom to the upper point of intersection of hopper side tank with side shell plating or inner hull, in m, see Figure 1.5.4.2(2). If there is no hopper side tank, $h_{HPL}$ is taken as 0.

$h_1$ — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_1 = \frac{B_H}{4}\tan\delta \quad \text{if } h_2 \geq 0$$

$$h_1 = \frac{B_2}{4}\tan\delta \quad \text{if } h_2 < 0$$

$M$ — mass of dry bulk cargo in cargo hold, in t;

$V_{TS}$ — total volume of lower stool of transverse bulkhead within cargo hold length $l_H$, in $m^3$. This does not include the portion of hopper side tank that passes through transverse bulkhead;

$B_H$, $l_H$ — see (1) of this paragraph;

$B_{IB}$ — average breadth of inner bottom, in m, see Figure 1.5.4.2 (2);

$\rho_C$ — density of dry bulk cargo, in $t/m^3$;

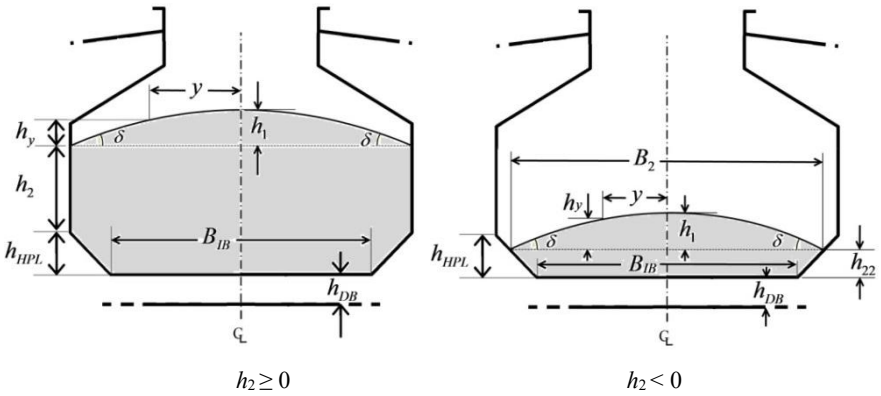
$\delta$ — angle of repose of cargo, determined as follows:

$\delta = 35°$ for ore and coal;

$\delta = 30°$ for salt, yellow sand, stone, grain, etc.;

$\delta = 25°$ for bulk cement;

$y$ — transverse distance from considered point to the longitudinal centerline section, in m.




$h_2 \geq 0$ $h_2 < 0$

**Figure 1.5.4.2(2) Definitions of $h_y$, $h_1$, $h_2$, $h_{22}$ and $h_{HPL}$**

(3) For a non-prismatic cargo hold, the top surface of dry bulk cargo may be taken at the horizontal surface of upper deck, and density taken as $M/V_H$, where $V_H$ is cargo hold volume, not including its portion enclosed by hatch coaming.

1.5.4.3 The total pressure $p_C$ caused by dry bulk cargo is to be calculated by the following formula and taken not less than zero:

$$p_C = \rho_C K_C (g + 0.5a_v)(h_C + h_{DB} - z) \quad \text{kN/m}^2$$

where:

$\rho_C$ — density of dry bulk cargo, in $t/m^3$;

$a_v$ — vertical acceleration in way of considered centroid of cargo hold, in $m/s^2$, see 1.5.2.2 (8) of this Section;

$h_C$ — vertical distance from the inner bottom to the top surface of dry bulk cargo, in m, determined according to 1.5.4.2 of this Section;

$h_{DB}$ — height of double bottom, in m;

$z$ — vertical height of the considered point, measured from baseline, in m;

$K_C$ — coefficient, to be calculated as follows:

$K_C = \cos^2\alpha + \tan^2(45^\circ - 0.5\delta)\sin^2\alpha$, for inner bottom, hopper side tank, transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool, inner hull and side plate;

$K_C = 0$, for top side tank, upper deck and inclined upper stool;

$\alpha$ — included angle between considered plate and horizontal plane, in deg;

$\delta$ — angle of repose of cargo, in deg, see 1.5.4.2(2) of this Section.

### 1.5.5 Liquid pressure in tank

1.5.5.1 The lateral pressure $p_l$ caused by liquid in tank is to be calculated by the following formula:

$$p_l = \rho g(h + 2.5 f_r) \qquad \text{kN/m}^2$$

where:

$\rho$ — mass density of liquid, in t/m$^3$, to be taken not less than 1.025 t/m$^3$;

$h$ — vertical distance from the considered point to top of tank, or half the vertical distance to the top of the overflow, whichever is the greater, in m;

$f_r$ — service coefficient, see 1.5.1.7 of this Section.

### 1.5.6 Direct strength calculation for cargo holds

1.5.6.1 The design load is to be in compliance with the following requirements:

(1) In general, the global load and local loads are to be taken into account, including vertical bending moment, external sea pressure, cargo loading, liquid pressure in tank, etc.

(2) The wave bending moment $M_w$ is to be calculated as in 2.2.3 of Section 2, Chapter 2 of this PART, and $f_r M_w$ is to be taken according to the service coefficient in 1.5.1.7 of this Section.

1.5.6.2 The extent of model is to be in compliance with the following requirements:

(1) Normally, the longitudinal extent is to cover the length of 1/2 hold + 1 hold + 1/2 hold within the cargo area amidships.

(2) In general, when both primary members and design loads are symmetrical to the longitudinal centerline section, only half breadth, starboard or port side is to be modeled. When the hold structure or load is not symmetrical to the longitudinal centerline section, a full-breadth model is to be required.

(3) The vertical extent is to be taken as all members within the main hull, including all the primary members on the main deck.

1.5.6.3 The element is to be selected in compliance with the following principles:

(1) In general, inner and external shell plates, deep webs of transverse rings, girders, floors, plane bulkhead web stiffeners, frames and other members as well as corrugated bulkheads and bulkhead stools are to be simulated by plate elements. In high stress areas and areas of significant stress gradient, such as lightening holes, manholes, connection of stool to bulkhead, positions adjacent to brackets or structural discontinuities, triangular elements are to be avoided as practicable as possible.

(2) Stiffeners of plates, which are subject to external sea pressure or cargo pressure, are simulated by beam elements, taking eccentric effects into consideration. The face plates and stiffeners of primary members (e.g. girders, floor stiffeners, frames and brackets may be simulated by rod elements.

1.5.6.4 The meshing of elements is to be in compliance with the following principles:

(1) Meshes are divided for each spacing of longitudinals or similar spacing in transverse and vertical direction of hull and for each spacing of frames or similar spacing in longitudinal direction of hull, and so are side meshes divided. Meshes are to be shaped square as far as practicable.

(2) Not less than three plate elements are to be arranged in vertical direction for bottom girders and floors. Not less than two plate elements are to be arranged in vertical direction for ring structures of hopper tanks and top wing tanks.

(3) In general, each flange plate or web plate of a corrugated bulkhead is to be taken at least as a plate element; for the plate elements at the lower end of the corrugated bulkhead in the vicinity of lower stool and for the elements adjacent to stool plate, the aspect ratio is to be close to 1.

(4) Normally, the aspect ratio of plate elements is not to exceed 3, and the aspect ratio of plate elements for corrugated bulkhead is not to exceed 2. Triangular plate elements are to be minimized in modeling as far as possible; the aspect ratio of plate elements is to be close to 1 as far as possible within the high stress area or area of high stress gradient and triangular plate elements are to be avoided.

1.5.6.5 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent.

1.5.6.6 When the stress distribution or stiffness of members is affected by the openings on primary members, the following methods may be adopted:

(1) For openings, e.g. lightening holes, manholes, of web plates of primary structural members, simulation is to be carried out according to Table 1.5.6.6 of this Section.

**Simulation of Openings of Web Plates of Primary Structural Members**

**Table 1.5.6.6**

| | |
|---|---|
| $h_0/h < 0.35$ and $g_0 < 1.2$ | Modeling not needed for openings |
| $0.35 \le h_0/h < 0.5$ and $g_0 < 1.2$ | Equivalent plate thickness being $t_1 = \dfrac{h-h_0}{h} t_w$ |
| $h_0/h < 0.5$ and $1.2 \le g_0 < 2$ | Equivalent plate thickness being $t_2 = \dfrac{h-h_0}{hg_0} t_w$ |
| $h_0/h \ge 0.5$ or $g_0 \ge 2$ | Modeling based on geometry of openings or by means of removing the appropriate elements in way of openings |

where: $t_w$ — thickness of web plates;

$l_0$ — opening length perpendicular to height of web plates, see Figure 1.5.6.6(1); where the space $d_0$ of continuous openings is less than 0.25 $h$, $l_0$ is to be taken as the length across the openings, see Figure 1.5.6.6(2);

$h_0$ — opening height parallel to height of web plates, see Figure 1.5.6.6(1);

$h$ — height of web plates in way of openings, see Figure 1.5.6.6(1);

$g_0 = 1 + \dfrac{l_0^2}{2.6(h-h_0)^2}$.

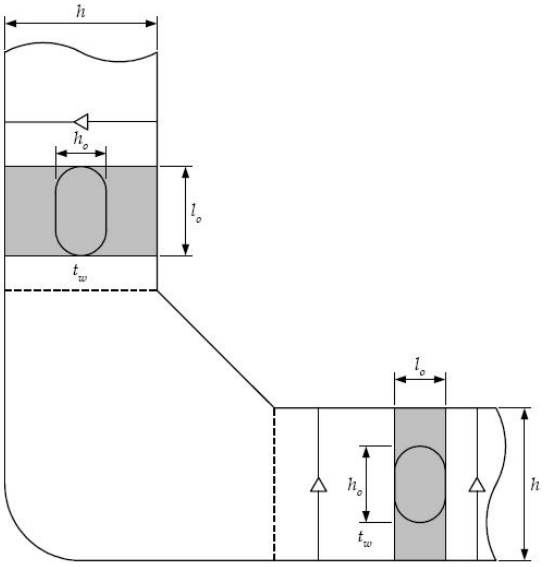



**Figure 1.5.6.6(1) Openings of Web Plates**

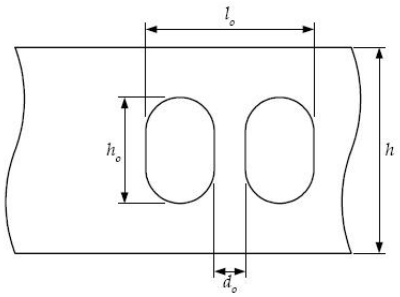



**Figure 1.5.6.6(2) Length $l_0$ for Space of Continuous Openings $d_0 < 0.25\ h$**

(2) For detailed stress analysis, the mesh size of the innermost two cycles of elements around the opening is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth. Stiffeners welded directly to the edges of the opening are to be simulated by plate elements; web stiffeners located more than 50 mm away from the edges of the opening can be simulated by rod or beam elements, as indicated in Figure 1.5.6.6(3). The allowable stress is to be as follows:

$$[\sigma_e] = 1.6 \times 235 / K \quad \text{N/mm}^2$$

where: $K$ — material factor.

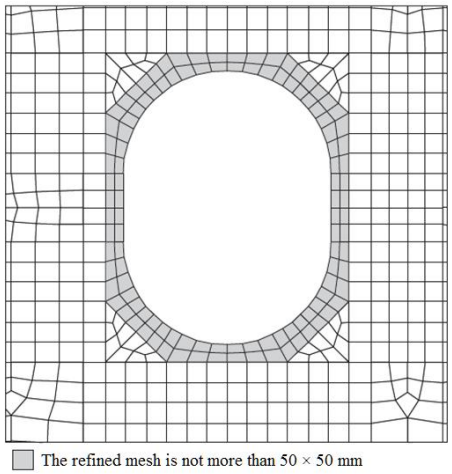



**Figure 1.5.6.6(3) Refined Opening of Web Plate**

### 1.5.7 Direct calculation of global strength of the ship

1.5.7.1 The flowchart of direct calculation of global strength of the ship is shown in Figure 1.5.7.1.

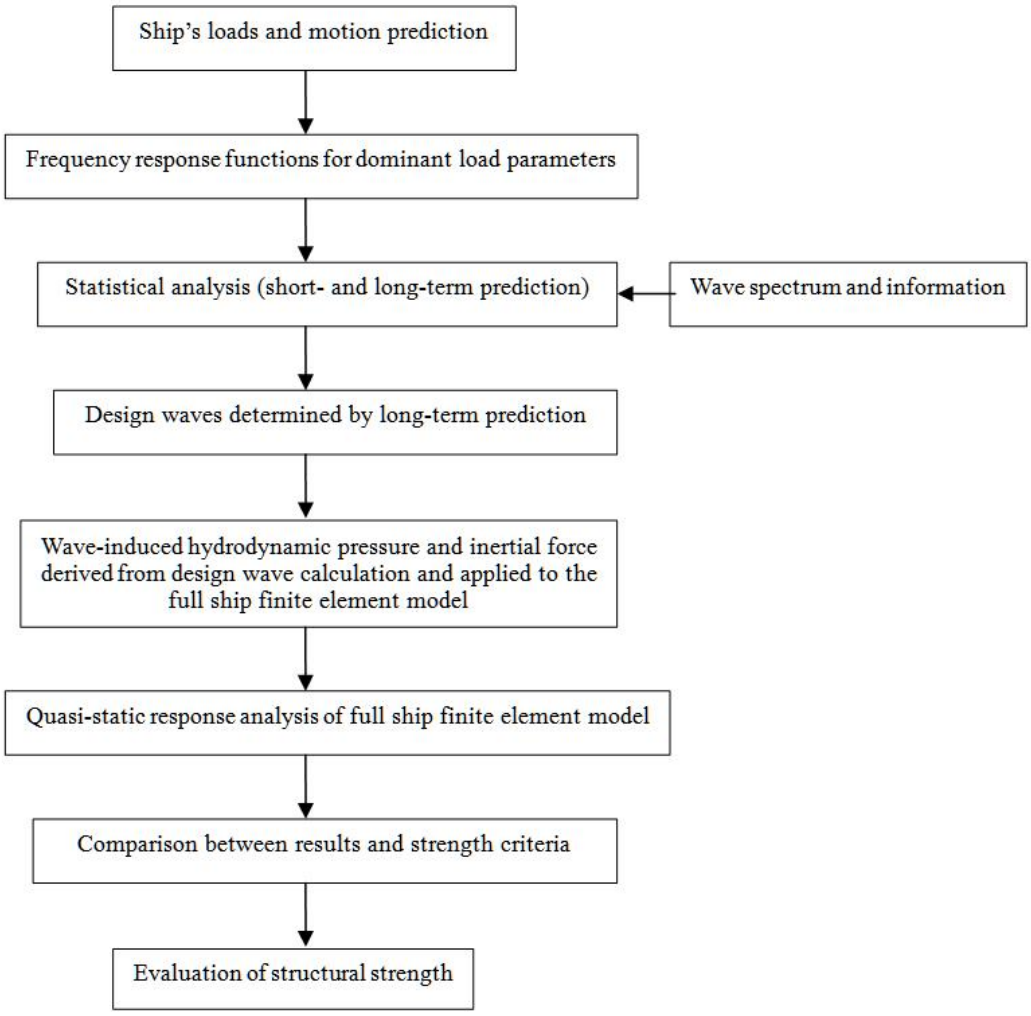



**Figure 1.5.7.1 Flowchart of Direct Calculation of Global Strength of the Ship**

1.5.7.2 The wave loads are to be determined by the equivalent design wave method, and in compliance with the following requirements:

(1) Ship motion and wave load are to be calculated based on the two-dimensional linear strip theory, the three-dimensional linear theory (considering non-linear corrections) or the non-linear wave theory.

(2) To calculate the ship motions and loads under design waves for each loading condition, the input data are considered as follows:

① the number of wave frequency (or wave length) is not to be less than 20, range of wave frequency taken as 0.2 to 3 according to the ratio of wave length to ship's length ( $\lambda / L$ ), and the increments taken as 0.1;

② not less than 7 wave heading angles are to be taken, including 0º (head sea), 30º, 60º, 90º, 120º, 150º, 180º (following sea);

③ ship speed is taken as 0.

1.5.7.3 Statistical analysis is to be carried out according to the following requirements:

(1) *P-M* wave spectrum is used for calculation of ship's motion on irregular waves, wave load response and its short- and long-term prediction:

$$S(\omega, H_{1/3}, T_2, \theta) = \begin{cases} \dfrac{2}{\pi} 124 H_{1/3}^2 T_2^{-4} \omega^{-5} \exp\left(-\dfrac{496}{T_2^4 \omega^4}\right) \cos^2 \theta, & |\theta| \le \dfrac{\pi}{2} \\ 0, & \theta \text{as other values} \end{cases}$$

where: $\omega$ — circular frequency of waves, in rad/s;

$H_{1/3}$ — significant wave height, in m;

$T_2$ — zero-crossing wave period, in sec.;

$\frac{2}{\pi}\cos^2\theta$ — energy spread function;

$\theta$ — included angle between complex wave and main sea direction, in rad.

(2) In the wave scatter diagram used in the calculations, the worst wave data of the ship navigating in service areas are used.

1.5.7.4 The design waves are to be calculated as follows:

(1) The design wave parameters are defined as shown in Figure 1.5.7.4(1):

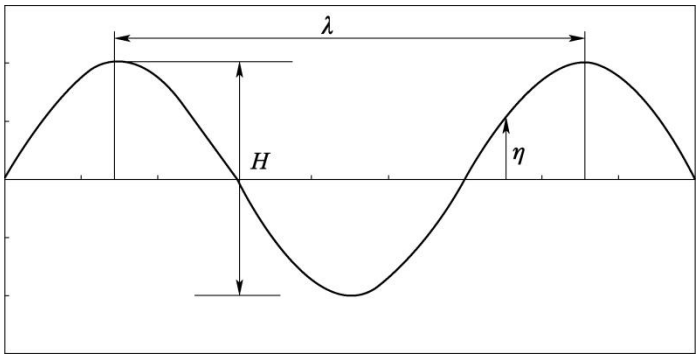



**Figure 1.5.7.4(1) Design Wave Parameters**

where:

$\lambda$ — wave length, minimum distance between two adjacent wave crests, in m;

$H$ — wave height, minimum distance from wave crest to wave trough, in m;

$\eta$ — wave surface, as sine equation.

(2) The probability level of long-term prediction values is to be selected according to the dominant load parameters.

(3) To calculate the curve of frequency response functions of dominant load parameters under different heading angles of regular waves, as shown in Figure 1.5.7.4(2).

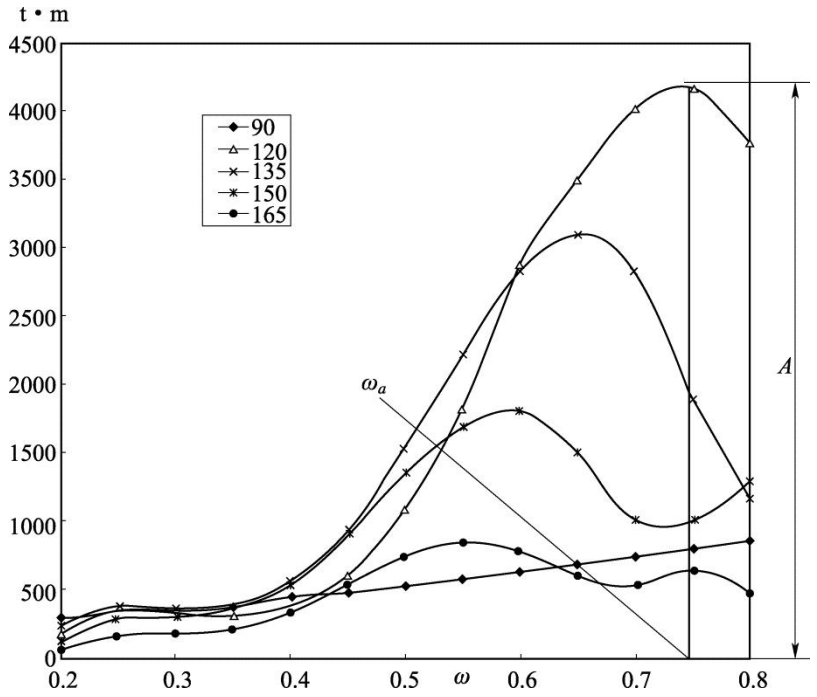



**Figure 1.5.7.4(2) Frequency Response Functions**

(4) The wave frequency $\omega_a$ where dominant load parameters are at the maximum amplitude are determined according to frequency response functions.

(5) Design wave length $\lambda$ is to be calculated as follows:

$$\lambda = (2\pi g)/\omega_a^2 \qquad \text{m}$$

where:

$\lambda$ — design wave length;

$g$ — gravitational acceleration;

$\omega_a$ — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s.

(6) Amplitude of design waves is to be calculated as follows:

$$a_w = \frac{L_j}{A_j}$$

where: $a_w$ — amplitude of design waves;

$A_j$ — maximum amplitude of dominant load parameters;

$L_j$ — long-term extreme value of dominant load parameter at the probability level according to 1.5.7.4(2);

$j$ — dominant load parameter number.

(7) The time $t_j$ instant where the dominant load parameter reaches maximum is to be determined as follows:

$$t_j = (n\pi + \pi/2 - \varepsilon_j)/\omega_a$$

where: $\omega_a$ — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s;

$\varepsilon_j$ — phase angle corresponding to dominant load parameters exceeding the maximum amplitude, in rad;

$j$ — as in 1.5.7.4(6);

$n$ — 0 or 1.

(8) Wave pressure and other load components under design waves are to be calculated as follows:

$$P_i = A_i a_w \sin(\omega_a t_j + \varepsilon_i)$$

where: $P_i$ — wave pressure or other load components at arbitrarily considered position of hull;

$A_i$ — amplitude of frequency response function of wave pressure or other load component $P_i$;

$\varepsilon_i$ — phase corresponding to wave pressure or other load component $P_i$;

$t_j$ — time instant where dominant load parameter reaches maximum, determined according to 1.5.7.4(7).

1.5.7.5 Load components and applying

(1) The ship's light weight: the masses of steel materials, outfits and small equipment are to be simulated by regulating the material density of each component. Large equipment and ballast water are to be simulated by mass elements, which may be established on the corresponding structures, and also may be connected to the actual structures through the simulated structures.

(2) The weight of cargo in hold and on deck is to be simulated by appropriate mass elements.

(3) External hydrostatic pressure, which acts, according to draft under the considered condition, on external wet surface of hull.

(4) Wave pressure is to be calculated according to the equivalent design wave method, acting on external wet surface of hull.

(5) Inertial load is to be based on the initial acceleration obtained by the equivalent design wave method, acting on the whole model.

1.5.7.6 The mass model of whole ship is to be matched with ship's hydrostatic buoyancy. The error between the total weight and total buoyancy is not to be more than $0.0001\Delta$, where $\Delta$ is the moulded displacement, in t, at the corresponding draught; the error of longitudinal coordinate for centers of mass and buoyancy is not to be more than $0.0025\,L$, where $L$ is the length of ship, in m; the error of horizontal coordinate is not to be more than $0.0001B$, where $B$ is the breadth of ship, in m.

### 1.5.8 Yield strength evaluation

1.5.8.1 The stress of members is not to exceed the relevant allowable stress criteria.

1.5.8.2 Membrane stress, i.e. median stress at center of bending plate element is to be taken for plate element.

1.5.8.3 For corrugated bulkheads, the stress in way of corrugation end may be obtained by extrapolation of average stresses of bulkhead plating.

1.5.8.4 For those elements of concentrated stress and poor shape, the stresses are not to be taken into consideration.

### 1.5.9 Buckling strength evaluation

1.5.9.1 The buckling safety factor $\lambda$ of plate panel is not to be less than the related minimum one.

1.5.9.2 The buckling strength evaluation of plate panel is to be carried out for all primary members. During the evaluation, the appropriate standard thickness deduction is to be taken into consideration for the critical buckling compressive stresses.

1.5.9.3 The biaxial compressive stress and shear stress are to be taken into account for the buckling strength evaluation and membrane stress of plate panel is to be used for the buckling strength evaluation.

1.5.9.4 Critical buckling stress and plastic correction

(1) The elastic critical buckling stress $\sigma_{xcr_e}$ of the plate panel, of which the shorter side is subjected to compression and bending, is defined as follows:

$$\sigma_{xcr_e} = k_x C_1 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: $k_x$ — buckling coefficient for shorter side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

$C_1$ — boundary constraint coefficient, see Table 1.5.9.4(2);

$t$ — thickness of plate panel, in mm;

$s$ — length of shorter side of plate panel, in mm, taken as spacing of stiffeners;

$E$ — material's elastic modulus, in N/mm$^2$;

$v$ — Poisson's ratio, $v = 0.3$ for steel;

$x$ — axial direction of longer side of plate panel.

(2) The elastic critical buckling stress $\sigma_{ycr_e}$ of the plate panel, of which the longer side is subjected to compression and bending, is defined as follows:

$$\sigma_{ycr_e} = k_y C_2 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: $k_y$ — buckling coefficient for longer side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

$C_2$ — boundary restraint coefficient, see Table 1.5.9.4(2);

$y$ — axial direction of shorter side of plate panel;

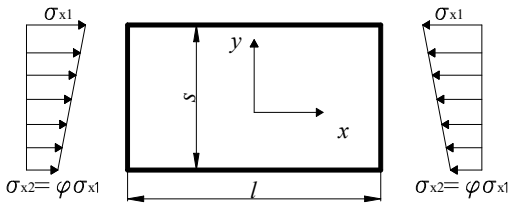
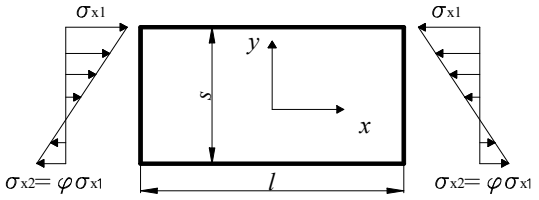
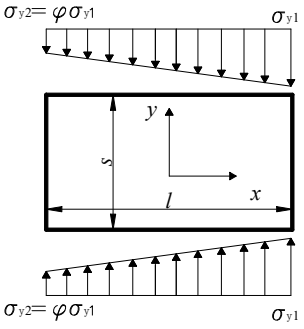
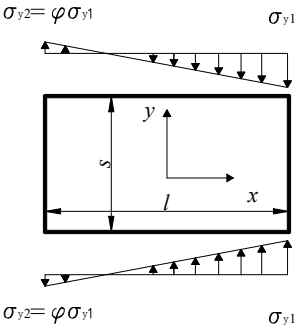
other symbols are the same as in 1.5.9.4(1).

(3) The elastic critical buckling stress $\tau_{cr_e}$ of plate panel subject to shear force is defined as follows:

$$\tau_{cr_e} = k_t C_1 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: $k_t$ — shear buckling coefficient, to be calculated according to Table 1.5.9.4(1);
other symbols are the same as in 1.5.9.4(1) and (2).

**Buckling Coefficient of Plate Panel** **Table 1.5.9.4(1)**

| Buckling load condition | | Buckling coefficient |
|---|---|---|
| Shorter side subject to stress |  where: $0 \le \varphi \le 1$ | $k_x = \dfrac{8.4}{\varphi + 1.1}$ |
| |  where: $-1 \le \varphi < 0$ | $k_x = 7.6 - 6.4\varphi + 10\varphi^2$ |
| Longer side subject to stress |  where: $0 \le \varphi \le 1$ | $k_y = \left[1+\left(\dfrac{s}{l}\right)^2\right]^2 \dfrac{2.1}{\varphi + 1.1}$ |
| |  where: $-1 \le \varphi < 0$ | $k_y = 1.909(1+\varphi)\left[1+\left(\dfrac{s}{l}\right)^2\right]^2 - k_p\varphi + 10\varphi(1+\varphi)\left(\dfrac{s}{l}\right)^2$<br>where:<br>$k_p = \begin{cases} 24\left(\dfrac{s}{l}\right)^2 & \dfrac{l}{s} \le \dfrac{3}{2} \\ 2+16\left(\dfrac{s}{l}\right)^2 + 8\left(\dfrac{s}{l}\right)^4 & \dfrac{l}{s} > \dfrac{3}{2} \end{cases}$ |

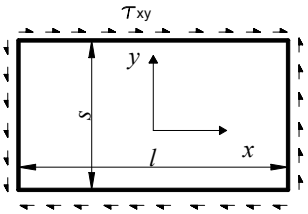
| Buckling load condition | | Buckling coefficient |
|---|---|---|
| Edges subject to shear stress |   | $k_t = 5.34 + 4\left(\frac{s}{l}\right)^2$ |

**Plate Panel Boundary Restraint Coefficients $C_1$ and $C_2$ Table 1.5.9.4(2)**

| Boundary | $C_1$ | $C_2$ | |
|---|---|---|---|
| | | In double bottom or between double sides | Elsewhere |
| Angles or T-stiffeners | 1.1 | 1.3 | 1.2 |
| Flat bars or bulb flats | 1.0 | 1.2 | 1.1 |

1.5.9.5 The elastic critical buckling stress of plate panel is to be corrected as follows:

$$\sigma_{\substack{xcr \\ (ycr)}} = \begin{cases} \sigma_{\substack{xcr_e \\ (ycr_e)}} & \text{when } \sigma_{\substack{xcr_e \\ (ycr_e)}} \le \dfrac{R_{eH}}{2} \\ R_{eH}\left(1 - \dfrac{R_{eH}}{4\sigma_{\substack{xcr_e \\ (ycr_e)}}}\right) & \text{when } \sigma_{\substack{xcr_e \\ (ycr_e)}} > \dfrac{R_{eH}}{2} \end{cases}$$

$$\tau_{cr} = \begin{cases} \tau_{cr_e} & \text{when } \tau_{cr_e} \le \dfrac{\tau_s}{2} \\ \tau_s\left(1 - \dfrac{\tau_s}{4\tau_{cr_e}}\right) & \text{when } \tau_{cr_e} > \dfrac{\tau_s}{2} \end{cases}$$

where:

$\sigma_{xcr_e}, \sigma_{ycr_e}, \tau_{cr_e}$ — respectively as elastic critical buckling compressive stress along axes *x* and *y* under uniaxial stress and critical buckling shear stress of plate panel, see 1.5.9.4 of this Section;

$R_{eH}$ — yield stress of material, in N/mm$^2$;

$\tau_s = \dfrac{R_{eH}}{\sqrt{3}}$.

1.5.9.6 In the buckling strength evaluation, the buckling safety factor $\lambda$ is to be the ratio of the critical buckling stress of plate panel to actual compressive stress, see Table 1.5.9.6. The $\sigma_x, \sigma_y, \tau_{xy}$ are considered in their absolute values in calculation. Where the working stress along axes *x* and *y* is of tension stress, such stress component is to be taken as zero.

**Calculation of $\lambda$** **Table 1.5.9.6**

| Stress condition \ Aspect ratio of plate panel | $1 \le \frac{l}{s} \le \sqrt{2}$ | $\sqrt{2} < \frac{l}{s} \le 8$ |
|---|---|---|
| Biaxial compression | $\frac{1}{(1+k_1)}\frac{\sigma_{xcr}}{\sigma_x}$ | $\frac{1}{\sqrt{(1+k_1^2)}}\frac{\sigma_{xcr}}{\sigma_x}$ |
| Compression along $x$ axis + edge shear | $\frac{1}{\sqrt{(1+k_2^2)}}\frac{\sigma_{xcr}}{\sigma_x}$ | |
| Compression along $y$ axis + edge shear | $\frac{1}{\sqrt{(1+k_3^2)}}\frac{\sigma_{ycr}}{\sigma_y}$ | |
| Biaxial compression + edge shear | $\frac{1}{\sqrt{(1+k_1^2+k_2^2)}}\frac{\sigma_{xcr}}{\sigma_x}$ | |

where: $k_1 = \frac{\sigma_y / \sigma_{ycr}}{\sigma_x / \sigma_{xcr}}$, $k_2 = \frac{\tau_{xy} / \tau_{cr}}{\sigma_x / \sigma_{xcr}}$, $k_3 = \frac{\tau_{xy} / \tau_{cr}}{\sigma_y / \sigma_{ycr}}$

Notes:

① $\sigma_{x1}$ and $\sigma_{y1}$ are greater values of working stress acting on sides of plate panel along axes $x$ and $y$, $\sigma_{x2}$ and $\sigma_{y2}$ are the lesser values of such stress, and $\sigma_x$ and $\sigma_y$ are to be taken as the average values of $\sigma_{x1}$, $\sigma_{x2}$ and $\sigma_{y1}$, $\sigma_{y2}$ respectively; $\tau_{xy}$ is the average shear stress, $\sigma_{x1}$, $\sigma_{x2}$, $\sigma_{y1}$, $\sigma_{y2}$, $\tau_{xy}$ are as shown in Table 1.5.9.4(1) of this Section.

② $\sigma_{xcr}$, $\sigma_{ycr}$ and $\tau_{cr}$ are the elastically corrected critical buckling compressive stresses under uniaxial stress and critical buckling shear stress of plate panel along axes *x* and *y* respectively.

# Section 6 CORROSION CONTROL FOR HULL STRUCTURES

### 1.6.1 General requirements

1.6.1.1 Effective means are to be taken for all ships to prevent excessive corrosion of hull members.

1.6.1.2 All seawater ballast tanks having boundaries formed by the hull envelope plating are to have an efficient protective coating, epoxy or equivalent, applied in accordance with the coating manufacturer's recommendation.

1.6.1.3 For bulk carriers, all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds, excluding the flat tank top areas and the hopper tanks sloping plating approximately 300 mm below the side shell frame and brackets, are to have an efficient protective coating (epoxy coating or equivalent). In the selection of coatings, due consideration is to be given by the Owner to the intended cargo conditions expected in service.

1.6.1.4 Right before application of coatings to any structure, surface preparation is to be made in accordance with coating manufacturer's workmanship requirements and the surfaces are to be thoroughly cleaned to a corresponding degree. The number of coatings and total dry film thickness are to comply with the design requirements.

1.6.1.5 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

1.6.1.6 Impressed current systems are not permitted in oil cargo tanks.

### 1.6.2 Primers or coatings

1.6.2.1 Where a primer is used to coat steel during construction, the primer is to be applied right after surface preparation. The composition of the primer is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control for structures. Primers are subject to approval in accordance with the relevant CCS requirements.

### 1.6.3 Internal cathodic protection in tanks

1.6.3.1 Where a cathodic protection system is to be fitted in tanks or adjacent tanks carrying liquid cargoes having a flash point not exceeding 60℃, a plan showing details of the locations and attachment of anodes is to be submitted for information.

1.6.3.2 When cathodic protection requirements are assessed, the effects of uncoated surfaces (e.g. tank fittings) adjacent to those which require protection are to be taken into account.

1.6.3.3 Aluminium alloy sacrificial anodes, magnesium alloy sacrificial anodes, zinc and zinc alloy sacrificial anodes of oil tankers

(1) Aluminium alloy sacrificial anodes are permitted in tanks used for the carriage of oil and adjacent tanks, but only at locations where the potential energy does not exceed 28 kg•m (200 lb•ft). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

(2) The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on horizontal surfaces (such as bulkhead girders and stringers) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

(3) Aluminium anodes are not to be located under tank hatches or Butterworth openings (in order to avoid any metal parts falling on the fitted anodes), unless protected by adjacent structure.

(4) Magnesium alloy sacrificial anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.

(5) Zinc alloy sacrificial anodes may be located in any position without restriction.

1.6.3.4 Arrangement of sacrificial anodes

(1) Anodes are to be reasonably located in relation to the structural features of the surfaces protected, and particular attention is to be given to the effects of adjacent structures and openings of the tank.

(2) Anodes are to be fitted with steel cores which are to be so designed as to retain the anode even when the latter is wasted. Anodes are to be sufficiently rigid to avoid resonance in the anode support.

(3) Anodes are to be efficiently attached to the structure. The following methods of attachment would be acceptable:

① steel core connected to the structure by continuous welding of adequate section;

② steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support;

③ approved means of mechanical clamping.

(4) Sacrificial anodes in tanks are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.
(5) Sacrificial anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating. Where cores or supports are welded to the structure, they are to be arranged so that the welds are clear of stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes be not fitted to face plates of higher tensile steel longitudinals in so far as practicable.

### 1.6.4 External hull protection

1.6.4.1 Shell plating, particularly the portion between light and loaded load lines, weather decks and hatch covers are to be provided with suitable corrosion protection.
1.6.4.2 Where an impressed current cathodic protection system is fitted, plans or information showing the proposed layout of anodes, reference electrodes, wiring and methods of attaching to the rudder and propeller, are to be submitted.
1.6.4.3 A small cofferdam is to be included in the arrangements for glands, where cables pass through the shell. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of at least 10 mm thickness.
1.6.4.4 For ships subject to in-water survey instead of drydocking survey, the underwater portion of the hull is to be coated with a high resistant paint. Details of the high resistant paint are to be submitted for information.

### 1.6.5 Corrosion allowance

1.6.5.1 Unless otherwise stated in this PART, the scantlings of hull structural members calculated in accordance with this PART are to include the values of corrosion allowance $t_c$ as specified here.
1.6.5.2 Corrosion allowances $t_c$ of hull structural members, including plating and framing, are to be obtained as in Table 1.6.5.2.

**Value of Corrosion Allowance $t_c$** **Table 1.6.5.2**

| Thickness $t$ (mm) | Corrosion allowance $t_c$ (mm) |
|---|---|
| ≤ 10 | 1.5 |
| > 10 | 0.1 $t$ + 0.5, maximum 3.2 |

1.6.5.3 For boundaries of ballast spaces or cargo tanks, the corrosion allowance is not to be less than 2.5 mm.
1.6.5.4 For dry spaces (cargo spaces in bulk carriers excluded), the corrosion allowances is to be $0.5t_c$ (see Table 1.6.5.2), but not less than 1.0 mm.

# Section 7 SHIPS NAVIGATING IN RESTRICTED SERVICE

### 1.7.1 General requirements

1.7.1.1 This Section applies to ships navigating in restricted service.

1.7.1.2 Those not covered in this Section are to comply with the relevant requirements of other chapters of this PART.

1.7.1.3 The definition of restricted service is referred to in Section 3, Chapter 1 of PART ONE.

### 1.7.2 Longitudinal strength

1.7.2.1 Where ships are subjected to the calculation for longitudinal strength in accordance with the requirements of Section 2, Chapter 2 of this PART, the minimum values of the midship section modulus $W_0$ may be reduced by:

(1) 5% for ships intended for greater coastal service;

(2) 10% for ships intended for coastal service;

(3) 15% for ships intended for sheltered water service.

1.7.2.2 Where ships are subjected to the calculation for longitudinal strength in accordance with the requirements of Section 2 of Chapter 2, or Sections 2 & 10 of Chapter 7 of this PART, the values of the wave bending moment and the wave shear force may be reduced by:

(1) 10% for ships intended for greater coastal service;

(2) 15% for ships intended for coastal service;

(3) 20% for ships intended for sheltered water service.

1.7.2.3 Where floating cranes and dredgers in operating conditions are subjected to the calculation for longitudinal strength in accordance with the requirements of Chapters 13 & 14 of this PART, the values of the wave bending moment and the wave shear force may be reduced by:

(1) 15% for ships intended for greater coastal service;

(2) 30% for ships intended for coastal service;

(3) 45% for ships intended for sheltered water service;

(4) 70% for ships intended for operation in harbours only.

### 1.7.3 Reduction of rule scantlings of structural members

1.7.3.1 For ships intended for navigating in restricted service, the scantlings of structural members, as calculated in accordance with the requirements of other chapters of this PART other than those of 1.7.3.2 and 1.7.3.3 of this Section, refer only to the Rule plate thickness, sectional area and section modulus of structural members, and may be reduced by:

(1) 5% for ships intended for greater coastal service;

(2) 10% for ships intended for coastal service;

(3) 15% for ships intended for sheltered water service.

The scantlings of structures after reduction are to comply with the requirements of 1.7.3.4 of this Section.

1.7.3.2 For ships equal to or greater than 65 m in length, where the values of the reduction factors $F_d$ and/or $F_b$ required in Section 2 of Chapter 2 of PART TWO are less than 1, the following requirements are to be complied with when calculating the thickness of shell plating and main deck within 0.4$L$ amidships:

(1) where the value of $F_d$ is less than 1, the thickness of main deck and sheer strake is not to be reduced in accordance with the requirements of 1.7.3.1 of this Section;
(2) where the value of $F_b$ is less than 1, the thickness of bottom plating and bilge strake is not to be reduced in accordance with the requirements of 1.7.3.1 of this Section;
(3) where the value of $F_d$ or $F_b$ is less than 1, the thickness of side shell plating is not to be reduced in accordance with the requirements of 1.7.3.1 of this Section.

1.7.3.3 The rule scantlings of the following structural members are not to be reduced in accordance with the requirements in 1.7.3.1:
the rule minimum thickness, scantlings of structural members for which ice strengthening and strengthening of bottom forward are required, and bulkhead, inner bottom plating and framing for loading heavy cargoes, cargo deck framing, vehicle decks, pillars, stems, stern frames, propeller shaft brackets, main engine seating structures, rudders, etc.

1.7.3.4 The requirements for thickness of plating after reduction
(1) For ships of less than 65 m in length, the thickness of shell plating is to be not less than 5 mm.
(2) For ships of less than 65 m in length, the thickness of strength deck is to be not less than 5 mm and the thickness of other decks is to be not less than 4 mm.
(3) For ships of less than 65 m in length, the thickness of inner bottom plating in double bottom is to be not less than 5 mm.
(4) For ships of less than 65 m in length, the thickness of weathertight steel hatch covers is to be not less than 5 mm.

1.7.3.5 For ships of less than 40 m in length, when calculating the thickness of transversely framed bottom plating, the value of spacing $s$ of frames may be taken as the actual spacing of frames.

1.7.3.6 The thickness of the plate keels is not to be less than the rule-specified calculated thickness of the bottom plating plus 1.5 mm, and in no case less than that of the adjacent bottom plating.

1.7.3.7 For ships intended for navigating in coastal service or sheltered water service, the requirements for strengthening of fore deck fittings in Section 9 of this Chapter may be dispensed with.

1.7.3.8 For ships intended for navigating in coastal service or sheltered water service, the requirements for strengthening of bottom forward in Section 15, Chapter 2 of this PART may be dispensed with.

1.7.3.9 For passenger ships intended for navigating in coastal service or sheltered water service, and of less than 65 m in length, the superstructure and deckhouse of tier 2 and above and not participating in hull girder longitudinal bending may use aluminium alloy densely reinforced plate. For passenger ships of 65 m and more in length, special consideration may be given to the superstructure and deckhouse not participating in hull girder longitudinal bending.

1.7.3.10 Where aluminium alloy densely reinforced plate is used in the superstructures and deckhouses mentioned in 1.7.3.9 above, the thickness of the plate may be determined in accordance with the principle of strength equivalence as specified in Section 17 of Chapter 2 and Section 2 of Chapter 9 of the PART, but not less than 5 mm.

### 1.7.4 Anchoring equipment

1.7.4.1 The anchoring equipment required in Section 2, Chapter 3 of this PART may be reduced in accordance with the following requirements:

(1) Except as required in (2) of this paragraph, for ships intended to navigate in coastal service, the anchoring equipment may be reduced by one grade in accordance with the equipment number *N*. For traffic boats or ferry boats less than 30 m in length, only one bower anchor is required and one half of the required length of chain cable may be fitted.

(2) For floating cranes, floating pile drivers or other similar working ships and trailing suction dredgers intended to navigate in coastal service, the anchoring equipment may be reduced by two grades in accordance with the equipment number *N*.

(3) For ships intended to navigate in sheltered water service, the anchoring equipment may be reduced by two grades in accordance with the equipment number *N*. For traffic boats or ferry boats of less than 30 m in length, only one bower anchor is required and one half of the required length of chain cable may be fitted.

(4) For ships intended to operate in port water areas with water-break, the anchoring equipment may be selected as half of the equipment number *N* and one half of the required length of chain cable may be fitted.

1.7.4.2 The ultra high holding power anchor may be used as bower anchor for ships navigating in restricted service. The mass of each ultra high holding power anchor may be 50% of that of an ordinary stockless bower anchor as so specified in Table 3.2.1.1 (2), Chapter 3 of this PART. The mass of each ultra high holding power anchor is generally not to exceed 1,500 kg, for details see Section 1, Chapter 10 of PART ONE of CCS Rules for Materials and Welding.

### 1.7.5 Openings and their closing appliances

1.7.5.1 Ventilators on ships intended for navigating in coastal service and sheltered water service need not be provided with closing appliances if the following requirements are met:

Ventilators in Position 1 the coamings of which extend to more than 4.5 m above the deck or twice the required standard height of other superstructure, whichever is lesser;

Ventilators in Position 2 the coamings of which extend to more than 2.3 m above the deck or the required standard height of other superstructure, whichever is lesser;

1.7.5.2 For the openings required in 1.8.7 of Section 8 of this Chapter in ships intended for navigating in sheltered water service, the height of their closing appliances above the deck may be determined according to Table 1.7.5.2.

Height Above Deck of Closing Appliances for Openings in Ships for Sheltered Water Service

(Unit:mm) Table 1.7.5.2

| Items of closing appliances | Sills of access openings in enclosed superstructures and deckhouses | Hatch coamings | Coamings of other flush scuttles | Sills of access openings in machinery casings | | Sills of doorways in companion ways | Ventilator coamings | | Air pipes |
|---|---|---|---|---|---|---|---|---|---|
| Paragraph | 1.8.7.1 | 1.8.7.2(1) | 1.8.7.2(1) | 1.8.7.3(1) | 1.8.7.3(2)&(6) | 1.8.7.2(3) | 1.8.7.4(6) | 1.8.7.4(3)&(4) | 1.8.7.5 |
| Position 1 | 250 | 450 | 300 | 300 | Outer sill 300<br>Inner sill 150 | 250 | 1000 higher than the next deck above | 450 | 300 |
| Position 2 | 100 | 300 | 150 | 150 | 150 | 100 | 1000 | 300 | 150 |

1.7.5.3 For engineering ships navigating and operating in harbours only, the height of the opening closing appliances above the deck may be reduced appropriately subject to agreement, provided that safe operation is not impaired, but is at least to meet the requirements for position 2 in Table 1.7.5.2.

# Section 8 STRUCTURAL ARRANGEMENT

### 1.8.1 General requirements

1.8.1.1 This Section specifies principled requirements for the arrangement of main hull structures.

1.8.1.2 Unless stated otherwise, this Section applies to mechanically self-propelled ships.

1.8.1.3 In addition to those specified in this Section, the provisions by the Administration of Chinese Government are to be complied with.

1.8.1.4 The length of the ship $L_{WL}$ is to be taken as the length measured between the extremities of the deepest subdivision waterline.

### 1.8.2 Arrangement of watertight bulkheads

1.8.2.1 All ships are to be fitted with at least the following watertight bulkheads:

(1) one collision bulkhead;

(2) one after peak bulkhead;

(3) one bulkhead at both ends of the machinery space.

### 1.8.3 Arrangement of collision bulkhead

1.8.3.1 The arrangement of the collision bulkhead of passenger ships is to comply with the following requirements:

(1) Ships are to be provided with watertight fore peak bulkheads or collision bulkheads to the bulkhead deck. This bulkhead is to be located at a distance from the forward perpendicular of not less than 5% $L_{WL}$ and not more than 3.0 m + 5% $L_{WL}$. Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distance specified above is to be measured from a point either:

①at the mid-length of such extension;

②at a distance 1.5% $L_{WL}$ forward of the forward perpendicular; or

③at a distance 3m forward of the forward perpendicular,

whichever gives the smallest measurement.

(2) Where a long forward superstructure is fitted, the fore peak bulkhead or the collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck of ships. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in (1) above with the exception permitted by (3) below and that the part of the deck which forms the step is made effectively weathertight.

(3) Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of ships, the part of the ramp which is more than 2.3 m above the bulkhead deck may extend forward of the limit specified in (1) above. The ramp is to be weathertight over its complete length.

1.8.3.2 The arrangement of the collision bulkhead of cargo ships is to comply with the following requirements:

(1) Ships are to be provided with watertight collision bulkheads to the freeboard deck. This bulkhead is to be located at a distance from the forward perpendicular of not less than 5% $L_{WL}$ or 10m, whichever is the less, and, except as may be permitted, not more than 8% $L_{WL}$. Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distance specified above is to be measured from a point either:

①at the mid-length of such extension;

②at a distance 1.5% $L_{WL}$ forward of the forward perpendicular; or

③at a distance 3m forward of the forward perpendicular,

whichever gives the smallest measurement.

(2) The collision bulkhead may have steps or recesses. No doors, manholes, ventilation ducts or any other openings are to be fitted in the collision bulkhead.

(3) Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the deck next above the freeboard deck of ships. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in (1) above with the exception permitted by (4) below and that the part of the deck which forms the step is made effectively weathertight.

(4) Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the freeboard deck of ships, the part of the ramp which is more than 2.3 m above the freeboard deck may extend forward of the limit specified in (1) above. The ramp is to be weathertight over its complete length.

(5) The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

### 1.8.4 Arrangement of after peak and machinery space bulkheads and stern tubes

1.8.4.1 The arrangement of after peak and machinery space bulkheads and stern tubes of passenger ships is to comply with the following requirements:

(1) Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and after and made watertight up to the bulkhead deck of ships. An aft peak bulkhead is also to be fitted. The aft peak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

(2) In all cases, stern tubes are to be enclosed in watertight spaces of moderate volume. The stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the margin line will not be immersed.

1.8.4.2 The arrangement of aft peak and machinery space bulkheads and stern tubes of cargo ships is to comply with the following requirements:

(1) Bulkheads must be fitted separating the machinery space from cargo and accommodation spaces forward and after and made watertight up to the freeboard deck of ships.

(2) Stern tubes are to be enclosed in watertight space(s) of moderate volume. Other measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements may be taken upon approval.

### 1.8.5 Arrangement and watertightness of openings and trunks in watertight bulkheads and internal decks

1.8.5.1 The number of the openings in watertight bulkheads are to be reduced to the minimum compatible with the design and proper working of the ship. These openings are to be provided with facilities to ensure the watertight integrity of the bulkhead.

1.8.5.2 Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in cargo ships.

1.8.5.3 For passenger ships, where trunkways or tunnels for access from crew accommodation to the stokehold, for piping, or for any other purpose are carried through watertight bulkheads, they are to be watertight. The access to at least one end of each such trunkway or tunnel, if used as a passage at sea, is to be through a trunk extending watertight to a height sufficient to permit access above the margin line. The access to the other end of the trunkway or tunnel may be through a watertight door of the type required by its location in the ship. Such trunkways or tunnels are not to extend through the first subdivision bulkhead abaft the collision bulkhead.

### 1.8.6 Openings in the shell plating below bulkhead deck/freeboard deck and freeing ports in bulwarks

1.8.6.1 The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

1.8.6.2 Freeing ports are to be capable of rapidly freeing the decks of water and draining them. The freeing port area in bulwarks is to meet following requirements:

(1) The minimum freeing port area (A) on each side of the ship for each well on the freeboard deck is to be that given by the following formula: The minimum area for each well on superstructure decks is to be one-half of the area given by the following formulae:

Where the length of bulwark $l$ in the well is 20 m or less:

$$A = 0.7 + 0.035l \quad \text{m}^2$$

Where $l$ exceeds 20 m, $A = 0.07l$ $\text{m}^2$

$l$ need in no case be taken as greater than 0.7 $L_L$.

If the bulwark is more than 1.2 m in average height, the required area is to be increased by 0.004 $\text{m}^2$ per meter of length of well for each 0.1 m difference in height. If the bulwark is less than 0.9 m in average height, the required area may be decreased by 0.004 $\text{m}^2$ per m of length of well for each 0.1 m difference in height.

(2) In ships with no sheer, the area calculated according to paragraph (1) is to be increased by 50%. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

(3) Where rails are not fitted on the weather parts of the freeboard deck in way of the trunk for at least half their length or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the minimum area of the freeing port openings are to be calculated from the following table:

| Breadth of hatchway or trunk<br>in relation to the breadth of ship | Area of freeing ports in relation to<br>the total area of the bulwarks |
|---|---|
| 40% or less | 20% |
| 75% or more | 10% |

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.
(4) In ships having superstructures on the freeboard deck or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.
(5) The lower edges of freeing ports are to be as near the deck as practicable. Two-thirds of the freeing port area required is to be provided in the half of the well nearest the lowest point of the sheer curve. One third of the freeing port area required is to be evenly spread along the remaining length of the weld. With zero or little sheer on the exposed freeboard deck or an exposed superstructure deck, the freeing port area is to be evenly spread along the length of the well.
(6) All freeing port openings in the bulwarks are to be protected by rails or bars spaced approximately 230 mm apart. If shutters are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. Shutters are not to be fitted with securing appliances.

### 1.8.7 Other openings and their closing appliances

1.8.7.1 All access openings in bulkheads at ends of enclosed superstructures are to comply with the following requirements:
(1) Doors of steel or other equivalent material are to be fitted, permanently and strongly attached to the bulkhead fitted so that the whole structure is of equivalent strength to the un-pierced bulkhead and weathertight when closed.
(2) Doors are to open outwards to provide additional security against the impact of the sea..
(3) The height of the doorsills is to be at least 380 mm above the deck.
1.8.7.2 Cargo and other hatchways, miscellaneous openings in freeboard and superstructure decks are to comply with the following requirements:
(1) The height of coamings of hatchways above the deck are to be at least as follows:
① 600 mm if in position 1; and
② 450 mm if in position 2.
(2) In addition to the provisions in (1), the structure of cargo and other hatchways in positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements for load line.
(3) Openings in freeboard and superstructure decks are to comply with following requirements:
① Manholes and flush scuttles in position 1 or 2 or within superstructures other than enclosed superstructures are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.
② Openings in freeboard decks other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength and weathertightness. Any such opening in an exposed superstructure deck, in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway. Doorways in such companionways or deckhouses are to be fitted with doors in accordance with 1.8.7.1 of this Section.

③ In position 1, the height above the deck of sills to the doorways in companionways is to be at least 600 mm. In position 2, it shall be at least 380 mm.

1.8.7.3 Machinery space openings are to comply with the following requirements:

(1) Machinery space openings are to be efficiently enclosed by steel casings. Access openings in such casings are to be fitted with weathertight doors, the sills of which are to be at least 600 mm above the deck if in position 1, and at least 380 mm above the deck if in position 2. Other openings in such casings are to be fitted with covers, permanently attached in their proper positions.

(2) Where machinery casings are not protected by other structures, double doors are to be required for ships assigned freeboards less than those based on relevant requirements. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

(3) Coamings of any machinery space ventilator, the height of which complies with the requirements of 1.8.7.4(6) of this Section, need not be fitted with weathertight closing appliances. Ventilators necessary to continuously supply the emergency generator room, if this is considered buoyant in the stability calculation or protecting opening leading below, are to have coamings of sufficient height to comply with 1.8.7.4(6) of this Section, without having to fit weathertight closing appliances.

(4) Where the height of machinery space and emergency generator room ventilator coamings is less than that required by 1.8.7.4, weathertight closing appliances are to be fitted.

(5) Fiddley openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

(6) Machinery casings on type 'A' ships are to be protected by one of the following arrangements:

① an enclosed poop or bridge of at least standard height; or

② a deckhouse of equal height and equivalent strength.

Machinery casings may, however, be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of 1.8.7.1 of this Section is acceptable in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine-room by a second weathertight door of steel or other equivalent material.

1.8.7.4 Ventilators are to comply with the following requirements:

(1) Ventilators in position 1 or 2 to spaces below freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. Where the coaming of any ventilator exceeds 900 mm in height, it is to be specially supported.

(2) Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

(3) Ventilators in position 1 are to have coamings of a height of at least 900 mm above the deck.

(4) Ventilators in position 2 are to have coamings of a height of at least 760 mm above the deck.

(5) The thickness of ventilator coamings may be taken from Table 1.8.7.4, but need not exceed that of the deck.

**Thickness of Ventilator Coaming** **Table 1.8.7.4**

| Internal diameter of coaming (mm) | Thickness of coaming (mm) |
|---|---|
| ≤200 | 7.5 |
| 250 | 8.0 |

| | |
|---|---|
| 300 | 8.5 |
| 350 | 9.0 |
| 400 | 9.5 |
| ≥450 | 10.0 |

(6) Ventilators in position 1 the coamings of which extend to more than 4.5 m above the deck, and in position 2 the coamings of which extend to more than 2.3 m above the deck need not be fitted with closing arrangements.

(7) Except as provided in (6) above, ventilator openings are to be provided with efficient weathertight closing appliances. In ships of not more than 100 m in load line length $L_L$, the closing appliances are to be permanently attached; in ships of more than 100 m in load line length $L_L$, they may be conveniently stowed near the ventilators to which they are to be fitted.

1.8.7.5 Air pipes are to comply with the following requirements:

(1) Air pipes are to comply with the requirements of this Section and in addition, the relevant requirements of Chapter 3 of PART THREE of the Rules.

(2) Where air pipes to ballast and other tanks extend above the freeboard or superstructure decks, the height from the deck to the point where water may have access below is to be at least 760 mm on the freeboard deck and 450 mm on the superstructure deck. The exposed parts of the pipes are to be of substantial construction.

(3) The minimum wall thickness of air pipes above weather deck is to be:

6.0 mm for pipes of 80 mm external diameter or smaller;

8.5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

(4) Air pipes are to be provided with automatic closing appliances.

### 1.8.8 Arrangement of double bottoms (not of tankers)

1.8.8.1 For all passenger ships regardless of size and cargo ships of 500 gross tonnage and over, a double bottom is to be fitted and is to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

1.8.8.2 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge. Any part of the inner bottom plating is not to be lower than the horizontal plane parallel to the keel line with a vertical distance not less than $h$ measured from the keel line. $h$ is calculated as follows:

$$h = B / 20$$

$h$ is in no case to be less than 760 mm, and need not be greater than 2000 mm.

1.8.8.3 Small wells constructed in the double bottom in connection with drainage arrangements are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than $h/2$ or 500 mm, whichever is greater, or it can be proved that this part of the ship complies with the requirements of 1.8.8.5 of this Section

Other wells (e.g. for lubricating oil under main engines) may be permitted if it can be proved that the arrangements comply with the requirements of 1.8.8.5 of this Section. As an equivalent provision, wells for lubricating oil under main engines may extend downward to the double bottom under the

boundary line defined by the distance *h*, but the vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than *h*/2 or 500 mm, whichever is greater.

1.8.8.4 A double bottom need not be fitted in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship, in the event of bottom or ship side damage, is not thereby impaired.

1.8.8.5 Any part of a passenger ship regardless of size and a cargo ship of 500 gross tonnage and over that is not fitted with a double bottom in accordance with 1.8.8.1, 1.8.8.3 or 1.8.8.4 of this Section is to satisfy the requirements for bottom damages, as specified in the Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, PART FOUR, Chapter 2-1, in that part of the ship.

### 1.8.9 Arrangement of cofferdams

1.8.9.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. A cofferdam is to be properly ventilated and of sufficient size to allow for inspection, maintenance and safe evacuation.

1.8.9.2 Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and those intended for fresh water (drinking water, water for propelling machinery and boilers).

Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and tanks intended for the carriage of liquid foam for fire extinguishing.

Cofferdams are only required between fuel oil tanks in double bottom and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides. Where a corner to corner situation occurs for such tanks, they are not considered to be adjacent.

1.8.9.3 The arrangement of cofferdams is also to comply with 2.8.2 of Section 8, Chapter 2 of PART THREE of the Rules.

### 1.8.10 Arrangement of bow freeboard deck and compartments forward of collision bulkhead

1.8.10.1 The arrangement of bow freeboard deck and enclosed superstructures, if fitted, is to comply with the requirements for minimum bow height by load line.

1.8.10.2 Fuel oil and other flammable oils are not to be carried in forepeak tanks and other compartments located forward of the collision bulkhead.

1.8.10.3 For ships for open sea service, spurling pipes and cable lockers are to be watertight up to the deck exposed to weather, and where means of access are provided, they are to be closed by a substantial cover and secured by closely spaced bolts.

1.8.10.4 For ships for other services, spurling pipes and cable lockers are to be watertight up to the freeboard deck, and where means of access are provided in spurling pipes and cable lockers below the freeboard deck, they are to be closed by a substantial cover and secured by closely spaced bolts. Where superstructures are provided, spurling pipes and cable lockers are to be weathertight from the freeboard deck up to the deck exposed to weather, and where means of access are provided in such extended spurling pipes and cable lockers, they are to remain closed weathertight.

### 1.8.11 Arrangement of passenger ships above the margin line

1.8.11.1 Measures are to be taken to limit the entry and spread of water above the bulkhead deck. Such measures may include partial bulkheads or webs. When partial watertight bulkheads and webs are fitted on the bulkhead deck, above or in the immediate vicinity of watertight bulkheads, they are to have watertight shell and bulkhead deck connections so as to restrict the flow of water along the deck when the ship is in a heeled damaged condition. Where the partial watertight bulkhead does not line up with the bulkhead below, the bulkhead deck between are to be made effectively watertight.

1.8.11.2 The bulkhead deck or a deck above it is to be watertight. All openings in the exposed weather deck are to have coamings of ample height and strength and are to be provided with efficient means for expeditiously closing them watertight. Freeing ports, open rails and scuppers are to be fitted as necessary for rapidly clearing the weather deck of water under all weather conditions.

1.8.11.3 In passenger ships, the open end of air pipes terminating within a superstructure is, in addition to compliance with 1.8.7.5 of this Section, to be at least 1 m above the waterline when the ship heels to an angle of 15º, or the maximum angle of heel during intermediate stages of flooding, as determined by direct calculation, whichever is the greater. Alternatively, air pipes from tanks other than oil tanks may discharge through the side of the superstructure.

1.8.11.4 Sidescuttles, gangway, cargo and fueling ports and other means for closing openings in the shell plating above the margin line are to be of efficient design and construction and of sufficient strength having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision load line.

1.8.11.5 Efficient inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be provided for all sidescuttles to spaces below the first deck above the bulkhead deck.

### 1.8.12 Arrangement of compartments of double hull oil tankers

1.8.12.1 Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of double bottom to the uppermost deck, disregrading a rounded gunwale where fitted. They are to be so arranged that all cargo tanks are located inboard of the moulded lines of the side shell plating in those tanks or spaces. The entire cargo tank (including slop tank) length of oil tankers of 5,000 tons deadweight and above are to be protected by ballast tanks or spaces other than tanks that carry oil, and the wing tanks and double bottom for such protection within the cargo tank length are to comply with the following requirements:

(1) The vertical distance $W$ between wing tank inner hull and side shell is not to be less than as calculated below:

$W = 0.5 + DW/20000$ m; or

$W = 2.0$ m

whichever is the lesser. The minimum value of $W = 1.0$ m.

where: $DW$ (Deadweight) means the difference in tons between the displacement of a ship in water of a relative density of 1.025 t/m$^3$ at the load line corresponding to the assigned summer freeboard and the lighweight of the ship.

(2) The depth of double bottom is not to be less than as calculated below:

$h = B/15$ m; or

$h = 2.0$ m

whichever is the lesser. The minimum value of $h$ = 1.0 m.

1.8.12.2 The wing tanks and double bottom of oil tankers of 600 tons deadweight or above but less than 5,000 tons deadweight are to comply with the following requirements:

(1) The vertical distance $W$ between wing tank inner hull and side shell is not to be less than as calculated below:

$W = 0.4 + 2.4\ DW/20000$ m;

the minimum value of $W = 0.76$ m

(2) The depth of double bottom is not to be less than as calculated below:

$h = B/15$ m;

the minimum value of $h$ = 0.76 m

1.8.12.3 The protection of cargo tanks is to comply with the requirements by the Administration of Chinese Government for prevention of oil tanker from oil pollution in collision or grounding accidents with regard to protection of such tanks by means of wing tanks or side spaces and double bottom tanks or other permitted methods.

1.8.12.4 Every crude oil tanker of 20,000 tons deadweight and above and every product carrier of 30,000 tons deadweight and above are to be provided with segregated ballast tanks. The capacity of the segregated ballast tanks is to be so determined that the ship may operate safely on ballast voyages without recourse to the use of cargo tanks for water ballast. The capacity of segreated ballast tanks is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballat only, the ship's draughts and trim can meet the following requirements:

(1) the moulded draught amidship ($d_m$ ), in m, (without taking into account any defomation of the ship) is not to be less than:

$d_m = 2.0 + 0.02L_L$ m

(2) the draughts at the forward and after perpendiculars are to correspond to those determined by the draught amidships as specified in (1) above, in association with the trim by the stern of not greater than $0.015L_L$ ; and

(3) the draught at the after perpendicular is not to be less than that which is necessary to obtain full immersion of the propeller(s).

1.8.12.5 Cargo tanks are to be of such size and arrangement that the hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

For oil tankers of less than 5,000 tons deadweight, the length of each cargo tank is not to exceed 10 m or one of the following values, whichever is the greater:

(1) where no longitudinal bulkhead is provided inside the cargo tanks: $(0.5b_i/B + 0.1)L_L$ , but not to exceed 0.2 $L_L$;

(2) where a centerline longitudinal bulkhead is provided inside the cargo tanks: $(0.25b_i/B + 0.15)L_L$;

(3) where two or more longitudinal bulkheads are provided inside the cargo tanks:

① for wing cargo tanks: 0.2 $L_L$

② for centre cargo tanks:

(a) if $b_i/B$ is equal to or greater than 1/5: 0.2 $L_L$

(b) if $b_i/B$ is less than 1/5:

(i) where no centerline longitudinal bulkhead is provided: $(0.5b_i/B + 0.1)L_L$

(ii) where a centerline longitudinal bulkhead is provided: $(0.25b_i/B + 0.15)L_L$

$b_i$ is the minimum distance from the ship's side to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centerline at the level corresponding to the assigned summer freeboard.

For oil tankers of less than 5,000 tons deadweight, the capacity of each cargo tank is not to exceed 700 $m^3$, unless wing tanks or spaces are arranged in accordance with 1.8.12.1(1), complying with the following:

$W = 0.4 + 2.4DW/20000$ m; the minimum value of $W = 0.76$ m.

1.8.12.6 The structures and arrangement of slop tanks, fuel oil tanks and cargo pump rooms are to comply with the provisions on pollution prevention for oil tankers by the Administration of China.

1.8.12.7 The structures and arrangement of fuel oil tanks and cargo pump rooms are to comply with the provisions on pollution prevention for oil tankers by the Administration of China.

### 1.8.13 Arrangement of tanks of single hull oil tankers

1.8.13.1 Cargo oil tanks of oil tankers of less than 600 tons deadweight may be of single hull construction.

1.8.13.2 The arrangement and size of cargo oil tanks are to comply with the requirements of 1.8.12.5 of this Section.

1.8.13.3 The structures and arrangement of slop tanks, fuel oil tanks and cargo pump rooms are to comply with the provisions on pollution prevention for oil tankers by the Administration of China.

### 1.8.14 Access to spaces in the cargo area of oil tankers

1.18.14.1 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is not to be less than 600 mm × 600 mm. The maximum value of the radius of the circle with the corresponding corner end as the center is not to be more than 100mm. If the clear opening size is larger than the above minimum size, the maximum value of the radius is also to be increased accordingly.When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

1.18.14.2 For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is not to be less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

1.18.14.3 For oil tankers of less than 5,000 tons deadweight, smaller dimensions for the openings may be accepted in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved, but in no case can the opening be less than 400 mm×600 mm or 450 mm×550 mm.

# Section 9 FORE DECK FITTINGS

### 1.9.1 Strength requirements for fore deck fittings and equipment

1.9.1.1 This Section provides strength requirements for the following items located within the forward 0.25$L$: air pipes, ventilator pipes and their closing devices. However, these requirements do not apply to the cargo tank venting systems and the inert gas systems of oil tankers.

1.9.1.2 All ships of 80 m or over in length, where the height of the exposed deck in way of the items as defined in 1.9.1.1 of this Section is less than 0.1$L$ or 22 m above the summer load waterline, whichever is the lesser, are to comply with the relevant requirements of 1.9.1 of this Section.

1.9.1.3 The pressures $p$, acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5\,\rho\, V^2 C_d C_s\, C_p \quad \text{kN/m}^2$$

where:

$\rho$ — density of seawater, taken as 1.025 t/m$^3$;

$V$ — velocity of water over the fore deck, in m/s;

= 13.5 m/s, for $h \le 0.5h_1$;

$$= 13.5\sqrt{2(1-\frac{h}{h_1})} \text{ m/s, for } 0.5h_1 < h < h_1;$$

where: $h$ — distance from summer load waterline to exposed deck, in m;

$h_1$— 0.1$L$ or 22 m, whichever is the lesser;

$C_d$ — shape coefficient, taken as 0.5 for pipes, 1.3 for air pipe or ventilator heads in general, 0.8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction;

$C_s$ — slamming coefficient, taken as 3.2;

$C_p$ — protection coefficient, taken as 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle, 1.0 elsewhere and immediately behind a bulwark.

1.9.1.4 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 1.9.1.3 of this Section using the largest projected area of each component.

1.9.1.5 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8 $R_{eH}$, where $R_{eH}$ is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

1.9.1.6 For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.9.1.6. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 1.9.1.6 but need not extend over the joint flange for the head. For air pipes of other heights, relevant requirements specified in 1.9.1.5 to 1.9.1.7 of this Section are to be met. Bracket toes at the deck are to be suitably supported.

**760 mm Air Pipe Thickness and Bracket Standards** **Table 1.9.1.6**

| Nominal pipe diameter (mm) | Minimum fitted gross thickness (mm) | Maximum projected area of head ($cm^2$) | Height① of brackets (mm) |
|---|---|---|---|
| 40③ | 6.0 | – | 520 |
| 50③ | 6.0 | – | 520 |
| 65 | 6.0 | – | 480 |
| 80 | 6.3 | – | 460 |
| 100 | 7.0 | – | 380 |
| 125 | 7.8 | – | 300 |
| 150 | 8.5 | – | 300 |
| 175 | 8.5 | – | 300 |
| 200 | 8.5② | 1900 | 300② |
| 250 | 8.5② | 2500 | 300② |
| 300 | 8.5② | 3200 | 300② |
| 350 | 8.5② | 3800 | 300② |
| 400 | 8.5② | 4500 | 300② |

Notes: ① Brackets (see 1.9.1.6) need not extend over the joint flange for the head.
② Brackets are required where the as-fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded.
③ Not permitted for new ships.
④ For air pipes of other heights, requirements specified in 1.9.1.5 to 1.9.1.11 of this Section are to be met.

1.9.1.7 For other configurations, loads according to 1.9.1.3 and 1.9.1.4 of this Section are to be applied, and means of support determined in order to comply with the requirements of 1.9.1.5 of this Section. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in Table 1.9.1.6 .

1.9.1.8 For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.9.1.8. Brackets, where required, are to be as specified in 1.9.1.6 of this Section.

**900 mm Air Pipe Thickness and Bracket Standards** **Table 1.9.1.8**

| Nominal pipe diameter (mm) | Minimum fitted gross thickness (mm) | Maximum projected area of head ($cm^2$) | Height of brackets (mm) |
|---|---|---|---|
| 80 | 6.3 | – | 460 |
| 100 | 7.0 | – | 380 |
| 150 | 8.5 | – | 300 |
| 200 | 8.5 | 550 | – |
| 250 | 8.5 | 880 | – |
| 300 | 8.5 | 1200 | – |
| 350 | 8.5 | 2000 | – |
| 400 | 8.5 | 2700 | – |
| 450 | 8.5 | 3300 | – |

| | | | |
|---|---|---|---|
| 500 | 8.5 | 4000 | – |

Note: For ventilators of other heights, requirements specified in 1.9.1.5 to 1.9.1.11 of this Section are to be met.

1.9.1.9 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted. Pipe thickness is not to be taken less than as indicated in 1.9.1.8.

1.9.1.10 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 1.9.1.3 and 1.9.1.4 of this Section.

1.9.1.11 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in 1.9.1.1 and 1.9.1.2 of this Section.

### 1.9.2 Strength and securing of small hatches on the exposed fore deck

1.9.2.1 The provisions of this Section apply to the strength of, and securing devices for, small hatches fitted on the exposed deck over the forward 0.25 $L$ ,where the height of the exposed deck in way of the hatch is less than 0.1 $L$ or 22 m above the summer load waterline, whichever is the lesser, for all ships of 80 m or over in length. This regulation does not apply to small hatches on container ship giving access to a cargo hold which comply with UI LL64 except the requirement of clauses 4 & 5. Such hatch covers are considered non-weathertight regardless of whether it is actually weathertight or not. However, for scantlings of small hatches, the strength requirements in 1.7.2.4-1.7.2.7 of this Section could be applied instead of clause 6 of UI LL64.

1.9.2.2 Small hatches are hatches designed for access to spaces below the deck and capable of being closed weather-tight or watertight, as applicable. Their opening is normally 2.5 $m^2$ or less.

1.9.2.3 Hatches designed for emergency escape need not comply with the requirements of 1.9.2.8(1), 1.9.2.8(2), 1.9.2.9(3) and 1.9.2.10 of this Section. Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover. The maximum force needed to open the securing device is not to exceed 150 N, and the use of a spring equalizing, counterbalance or other suitable device on the hinge side to reduce the force needed for opening such hatch covers is acceptable.

1.9.2.4 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 1.9.2.4 and Figure 1.9.2.4. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, as required in 1.9.2.9(1) of this Section, see Figure 1.9.2.4. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.9.2.9.

**Scantlings for Small Steel Hatch Covers on Fore Deck** **Table 1.9.2.4**

| Nominal size (mm×mm) | Cover plate thickness (mm) | Primary stiffeners | Secondary stiffeners |
|---|---|---|---|
| | | Flat bar (mm × mm); number | |
| 630 × 630 | 8 | – | – |
| 630 × 830 | 8 | 100 × 8; 1 | – |
| 830 × 630 | 8 | 100 × 8; 1 | – |
| 830 × 830 | 8 | 100 × 10; 1 | – |
| 1030 × 1030 | 8 | 120 × 12; 1 | 80 × 8; 2 |
| 1330 × 1330 | 8 | 150 × 12; 2 | 100 × 10; 2 |

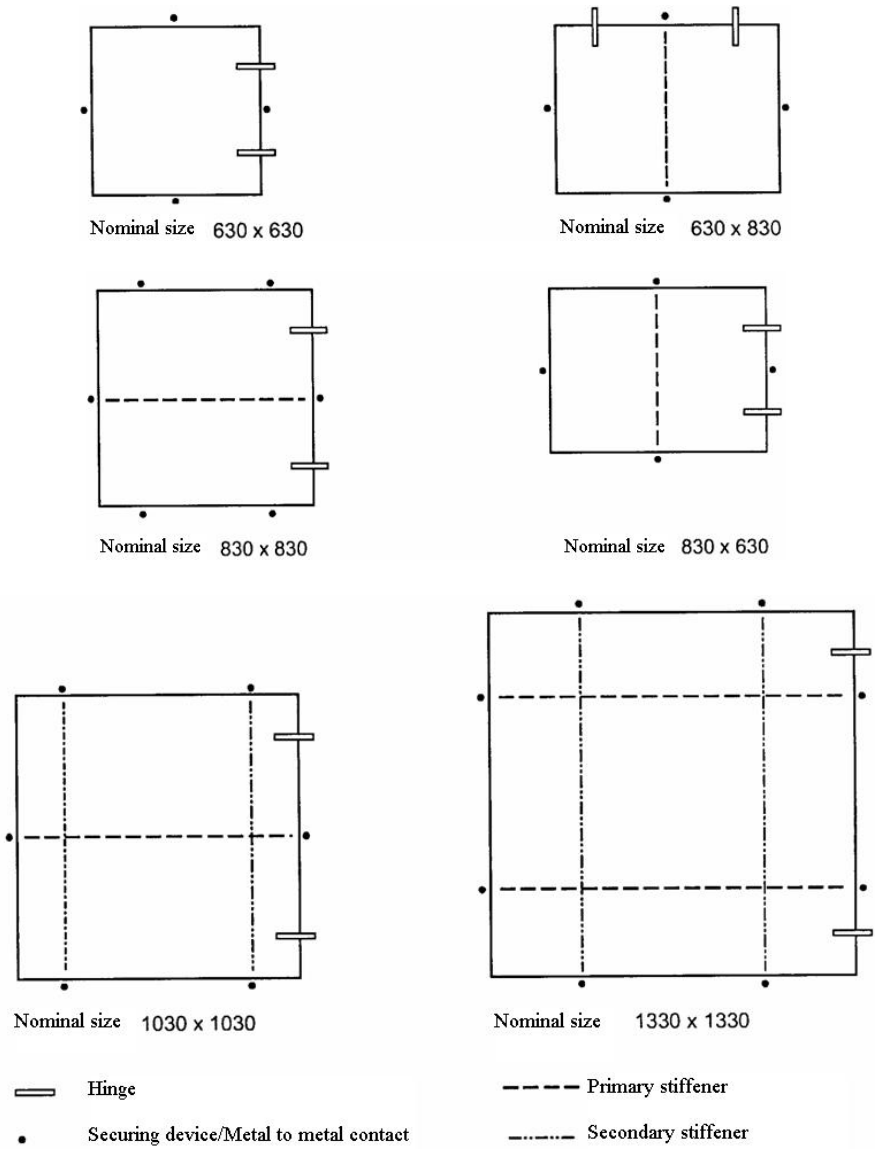



**Figure 1.9.2.4** (Unit: mm × mm)

1.9.2.5 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

1.9.2.6 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength equivalent to that of the surrounding structure.

1.9.2.7 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

1.9.2.8 Small hatches located on exposed fore deck are to be fitted with any one of the following primary securing devices:

(1) butterfly nuts tightening onto forks (clamps);

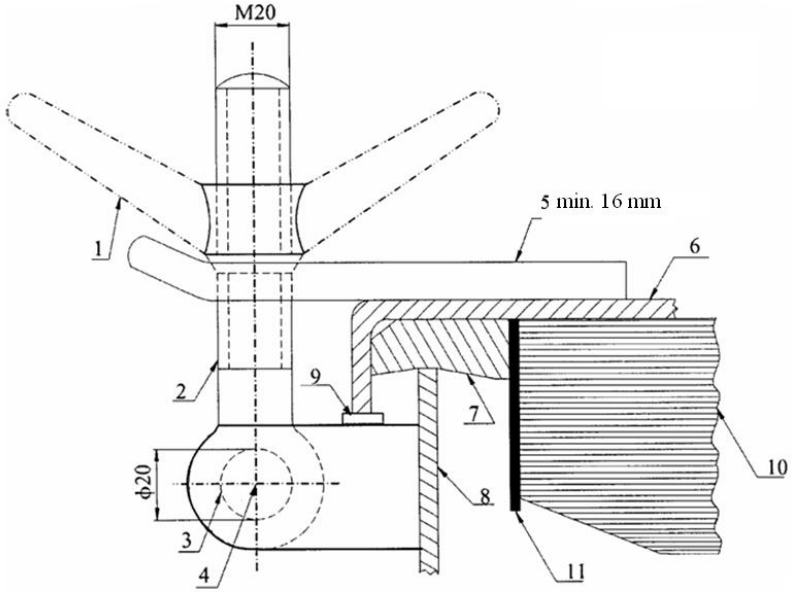
(2) quick acting cleats; or

(3) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

1.9.2.9 The following requirements are to be complied with for primary securing devices:

(1) The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 1.9.2.4, and of sufficient capacity to withstand the bearing force.
(2) The primary securing devices are to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.
(3) For a primary securing device using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of forks is not to be less than 16 mm. An example arrangement is shown in Figure 1.9.2.9 .
(4) For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted on the fore edge of the cover such that the predominant direction of green sea will cause the cover to close.
(5) On small hatches located between the main hatches, for example between No.1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.




1. butterfly nut; 2. bolt; 3. pin; 4. center of pin; 5. fork (clamp) plate; 6. hatch cover; 7. gasket; 8. hatch coaming; 9. bearing pad welded on the bracket of a toggle bolt for metal to metal contact; 10. stiffener; 11. inner edge stiffener

**Figure 1.9.2.9**

1.9.2.10 Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

# Section 10 TANK SLOSHING

### 1.10.1 General requirements

1.10.1.1 For partially loaded tank, a strength assessment of tank structure under sloshing loads (hereinafter referred to as 'Sloshing Assessment') is to be carried out according to the requirements of this Section.

1.10.1.2 For those not covered by this Section, the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks are to be met.

1.10.1.3 Unless otherwise specified, for tanks with internal members, partial filling generally means the liquid filling height is greater than 10% of the tank depth but less than 90% of the tank depth. For smooth tank, partial filling generally means the liquid filling height is greater than 5% of the tank depth but less than 95% of the tank depth.

1.10.1.4 Unless specially specified, the sloshing assessment specified in this Section includes both transverse and longitudinal sloshing motions.

1.10.1.5 According to the judgment of the sloshing resonance of ship and tank, the sloshing motion and loads are divided into levels 1, 2 and 3. For tanks complying with sloshing motion level 1, sloshing loads at sloshing motion level 1 are to be calculated. For tanks complying with sloshing motion level 2, sloshing loads at sloshing motion levels 1 and 2 are to be calculated. For tanks complying with sloshing motion level 3, sloshing loads at sloshing motion levels 1, 2 and 3 are to be calculated.

1.10.1.6 In order to reduce sloshing motion level, internal members may be added for swash or limit on the filling may be taken to avoid sloshing resonance.

### 1.10.2 Application

1.10.2.1 This Section is applicable to tankers such as oil tankers, chemical tankers, liquefied gas carriers, and bulk carriers, ore carriers and dry cargo carriers etc.

1.10.2.2 This Section is applicable to all cargo tanks, ballast tanks and other tanks where free surface motion is allowed.

1.10.2.3 For ships the length of which is less than 100 m, the level 3 longitudinal sloshing assessment is not to be considered if the tank effective sloshing length does not exceed 0.16 $L$ during the sloshing assessment. If the tank effective sloshing breadth does not exceed 0.6B (B is the ship breadth), level 3 transverse sloshing assessment is not to be considered.

1.10.2.4 Longitudinal sloshing assessment may not be required for tanks meeting one of the following conditions:

(1) the length of ship is less than 65 m and the effective sloshing length does not exceed 0.13$L$;

(2) the effective sloshing length is less than 0.03$L$.

1.10.2.5 Transverse sloshing assessment may not be required for tanks meet one of the following conditions:

(1) the length of ship is less than 65 m and the effective sloshing breadth does not exceed 0.56$B$;

(2) the effective sloshing breadth is less than 0.32$B$.

1.10.2.6 Sloshing assessment may not be required for tanks meet one of the following conditions:

(1) tank capacity is not greater than 100 $m^3$;

(2) tanks fitted in double bottom or double skin or other tanks of cellular construction;
(3) dry cargo holds used for ballasting of bulk carriers.

### 1.10.3 Plans and documents

1.10.3.1 Tank boundary structure plan, internal member structure plan of tank (if any) are to be submitted for approval during the sloshing assessment carried out in accordance with the requirements of this Section.

1.10.3.2 Sloshing loads and hull structural strength assessment report are to be submitted for information.

### 1.10.4 Sloshing loads calculation

1.10.4.1 Unless otherwise specified, the sloshing motion and the calculation of the loads specified in this Section are to meet the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

1.10.4.2 The results of sloshing model test may be taken as the alternative for sloshing design loads when approved.

### 1.10.5 Strength assessment

1.10.5.1 Scantling assessment under sloshing loads are to be carried out to the following structural members:
(1) plating forming tank boundaries, stiffeners;
(2) plating and stiffeners on wash bulkheads in the tank;
(3) web of primary support members, web stiffeners in the tank.

1.10.5.2 Unless otherwise specified, scantling assessment under sloshing loads is to meet the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

# CHAPTER 2 HULL STRUCTURES

## Section 1 GENERAL PROVISIONS

### 2.1.1 Application

2.1.1.1 This Chapter applies mainly to dry cargo ships. If not covered in this Chapter, the requirements of Chapter 1 of this PART are to be complied with.

2.1.1.2 This Chapter applies to the basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement, and with the hatch openings of normal dimensions.

2.1.1.3 Longitudinal framing is in general to be adopted at the strength deck outside the line of openings and at the bottom.

2.1.1.4 For ships with self-unloading system, such system is to meet the relevant requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

### 2.1.2 Plans and documents

2.1.2.1 Plans and documents covering the following items are to be submitted for approval. In the case of special constructions and arrangements, additional plans and documents may be required if considered necessary:

(1) Principal transverse sections;

(2) Construction profile, including longitudinal sections, decks, inner bottom, superstructures and deckhouses;

(3) Stem;

(4) Stern frame;

(5) Shell expansion;

(6) Oiltight and watertight bulkheads;

(7) Main engine seating and thrust bearing seating;

(8) Propeller shaft bracket;

(9) Hatch coamings;

(10) Cargo hatch covers;

(11) Arrangement of anchoring equipment including equipment number calculations;

(12) Rudder, rudder stock and tiller;

(13) Masts, derrick posts and crane pedestals, together with their support structures;

(14) Ice strengthening with calculations;

(15) Welding, including type and size of welds;

(16) Preliminary and finished loading manuals.

2.1.2.2 The following plans and documents are to be submitted for information:

(1) General arrangement;

(2) Lines or offsets;

(3) Body plan (frame lines);

(4) Capacity plan;
(5) Specifications for hull and equipment;
(6) Longitudinal strength calculations (where applicable);
(7) Direct strength calculation report (where applicable);
(8) Fatigue strength assessment report (where applicable).

# Section 2 LONGITUDINAL STRENGTH

### 2.2.1 General requirements

2.2.1.1 For ships of 65 m and over in length, their longitudinal strength is to be checked in accordance with the requirements of this Section. For ships of unusual type or special loading and less than 65 m in length, their longitudinal strength may also be checked in accordance with the requirements of this Section.

For container ships of 90 m and over in length or ships dedicated primarily to carry their load in containers, their longitudinal strength is to comply with the requirements of Section 2, Chapter 7 of this PART and of 2.2.5.1 of this Section.

2.2.1.2 For ships complying with the following conditions, special considerations are required for longitudinal strength:

(1) For ships having one or more of the following characteristics, direct calculations are in general to be carried out, of which, direct calculation of wave loads is given in 2.2.9 of this Section:

$$L/B \leqslant 5$$
$$B/D \geqslant 2.5$$
$$L \geqslant 500\text{m}$$
$$C_b < 0.6$$

(2) For ships having large deck openings, the longitudinal strength at combined bending and torque is to be checked according to the requirements in Section 10, Chapter 7 of this PART.

(3) For ships having large flare, additional bending moment caused by slamming may be considered.

(4) For ships intended for the carriage of special cargoes (e.g. heated cargoes), ships of unconventional type or ships of unconventional design, direct calculations are to be carried out in accordance with properties of cargoes or ship's type; where direct calculations are impracticable, design loads are to be determined by means of model test.

### 2.2.2 Design still water bending moment and shear force

2.2.2.1 The still water bending moment and shear force at each transverse section along the ship's length are to be calculated from the following conditions:

In loaded conditions: departure, arrival;

In ballast conditions: departure, arrival.

Various loading conditions included in the Loading Manual are also to be taken into account in the calculation.

2.2.2.2 In calculation of still water bending moments and shear forces, the downward loads are to be taken as positive values, the upward loads as negative values, and are to be integrated in the forward direction from the aft end of the length of the ship. The sign conventions of the still water bending moments $M_s$ and shear forces $F_s$ are as shown in Figure 2.2.2.2.

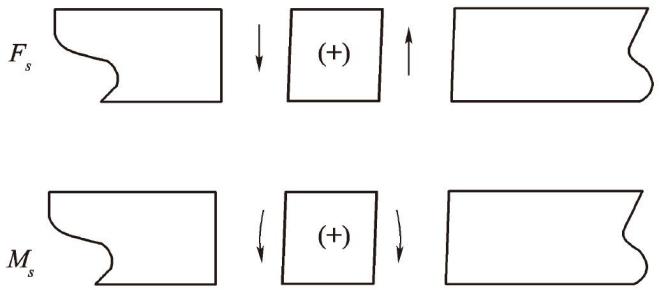



**Figure 2.2.2.2**

2.2.2.3 In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the $M_s$ and $F_s$ calculations.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

(1) General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:

① homogeneous loading conditions at maximum draught;

② ballast conditions;

③ special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable;

④ short voyage or harbor conditions, where applicable;

⑤ docking condition , afloat;

⑥ instantaneous conditions of loading and unloading, where applicable.

(2) Oil tankers:

① homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part-loaded conditions;

② any specified non-uniform distribution of loading;

③ mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions;

④ docking condition, afloat;

⑤ instantaneous conditions of loading and unloading, where applicable.

(3) Chemical tankers:

① conditions as specified for oil tankers;

② conditions for high density or segregated cargo.

(4) Liquefied gas carriers:

① homogeneous loading conditions for all approved cargoes;

② ballast conditions;

③ cargo condition where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities are carried;

④ harbor conditions where increased steam pressure is approved;

⑤ docking condition, afloat.

(5) Combination carriers:

① conditions as specified for oil tankers and cargo ships.

2.2.2.4 Partially filled ballast tanks in ballast loading conditions (relevant guidance and interpretation are given in Appendix 3 of Chapter 2, PART TWO in CCS Rules for Classification of Sea-going Steel Ships).

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 2.2.2.3 of this Section, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty;
- full;
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion ($I/D$) not less than 25%, where:

  $I$ — the distance from propeller centerline to the waterline;

  $D$ — propeller diameter (see Figure 2.2.2.4).

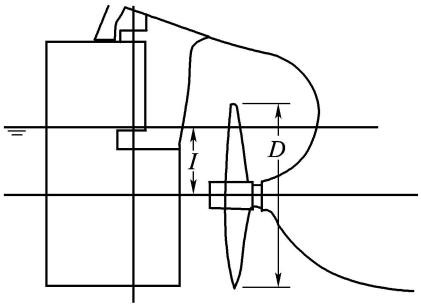



**Figure 2.2.2.4**

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

2.2.2.5 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirements in 2.2.2.4 of this Section apply to the peak tanks only.

### 2.2.3 Wave bending moment and wave shear force

2.2.3.1 The hogging and sagging wave bending moments $M_W(+)$ and $M_W(-)$ at each transverse section along the ship's length are to be obtained from the following formulae:

$$M_W(+) = +190MCL^2BC_b \times 10^{-3} \quad \text{kN·m}$$

$$M_W(-) = -110\,MCL^2B(C_b + 0.7) \times 10^{-3} \quad \text{kN·m}$$

where: $M$ — distribution factor of bending moment, see Figure 2.2.3.1;

$L$ — length of ship, in m;

$B$ — breadth of ship, in m;

$C_b$ — block coefficient, taken not less than 0.60;

$C$ — coefficient to be obtained from the following formulae:

$C = 0.0412L + 4$ for $L < 90$ m;

$C = 10.75 - \left(\frac{300 - L}{100}\right)^{3/2}$ for $90 \leqslant L \leqslant 300$ m;

$C = 10.75$ for $300 < L < 350$ m;

$C = 10.75 - \left(\frac{L - 350}{150}\right)^{3/2}$ for $350 \leqslant L \leqslant 500$ m.

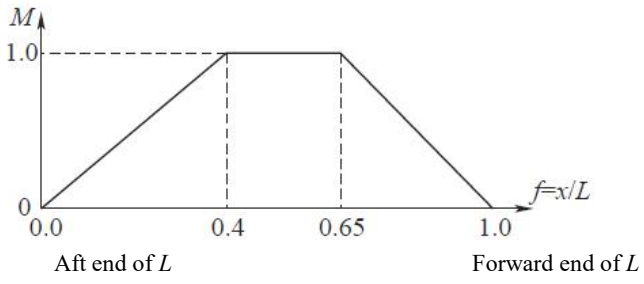



**Figure 2.2.3.1**

2.2.3.2 The hogging and sagging wave shear forces $F_w$ (+) and $F_w$ (−) at each transverse section along the ship's length are to be obtained from the following formulae:

$$F_w\,(+) = +30F_1CLB(C_b+0.7)\times10^{-2} \qquad \text{kN}$$

$$F_w\,(-) = -30\,F_2CLB(C_b+0.7)\times10^{-2} \qquad \text{kN}$$

where: $F_1$, $F_2$ — shear force distribution factor given in Figure 2.2.3.2(1) and Figure 2.2.3.2(2);

$C$ — coefficient to be obtained from 2.2.3.1 of this Section;

$C_b$ — see 2.2.3.1 of this Section;

$L$ — length of ship, in m;

$B$ — breadth of ship, in m.

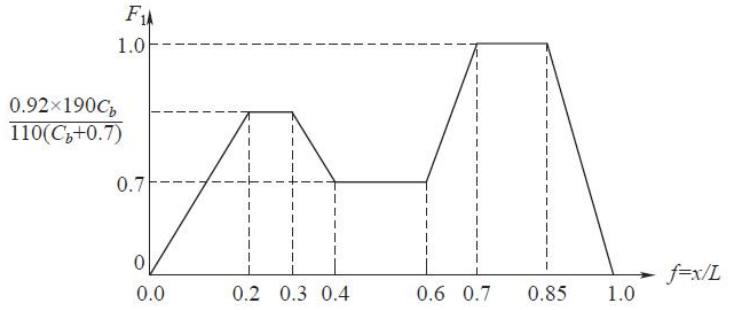



**Figure 2.2.3.2(1)**

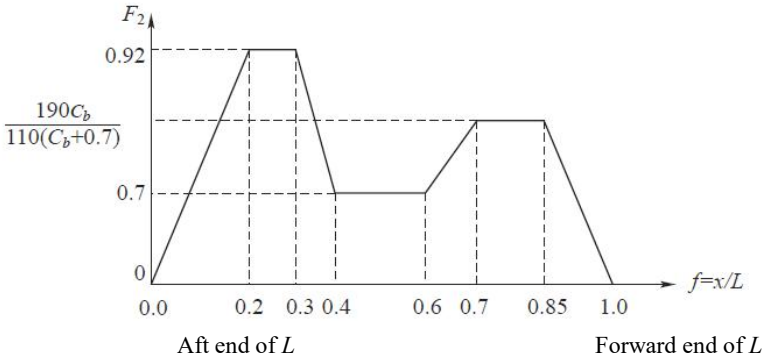



**Figure 2.2.3.2(2)**

### 2.2.4 Calculation of hull girder section properties

2.2.4.1 The moment of inertia of the hull girder section about its horizontal neutral axis divided by the vertical distance from the neutral axis to the top of strength deck at side gives the hull girder section modulus $W_d$ at the strength deck; and that divided by the vertical distance from the neutral axis to the top of keel gives the hull girder section modulus $W_b$ at bottom.

2.2.4.2 The strength deck and all continuous longitudinal members below the strength deck within 0.4$L$ amidships may be included in the calculation of hull girder section modulus. The extension of the sheer strake above the strength deck and the continuous stringer angles may be included in the calculation. Where trunck decks or continuous hatch coamings (except inboard coamings of multi-hatch arrangements) above the strength deck are effectively supported by

longitudinal bulkheads or deep girders, their sectional area may also be included in the calculation of the hull girder section modulus.

2.2.4.3 For multi-hatch arrangements, the effective sectional area for the inboard continuous hatch coaming and supporting members below is to be determined by direct calculation in accordance with support conditions. The following provision is applicable to cases without detailed calculation:

(1) Where a continuous longitudinal underdeck girder, or girders, are arranged to support the inboard hatch coamings, 50% of their sectional area are to be included in the calculation of the hull girder section modulus. If the girder is fitted in conjunction with a longitudinal bulkhead, 100% of the sectional area may be included. In cases where the girders are enclosed box sections, or where the girders are not enclosed box sections and are adequately supported and effectively tied to the bottom structure, 80% of their sectional area may be included. The slender ratio of the above-mentioned girders is not to be greater than 60.

(2) The percentage of the sectional area to be included for inboard continuous hatch coamings is to be the same percentage as that of the longitudinal girder under.

2.2.4.4 For the cases in 2.2.4.2 and 2.2.4.3 of this Section, when calculating the hull girder section modulus, the lever $Z_t$, vertical distance from the point considered to the neutral axis, is to be taken as follows, with $Z_t$ being greater than the vertical distance from the neutral axis to the moulded deck line at side:

$$Z_t = Z_c\left(0.9 + 0.2\frac{y}{B_1}\right) \qquad \text{m}$$

where: $Z_c$ — vertical distance from the neutral axis to the top of the continuous strength member, in m;

$y$ — horizontal distance from the top of the continuous strength member to the centerline of the ship, in m;

$B_1$ — breadth of ship at section considered, in m.

In calculation, $Z_c$ and $y$ are to be measured to the point giving the maximum value of $Z_t$.

2.2.4.5 Where deck longitudinals or deck girders are arranged above the strength deck, the sectional area may be included in the calculation of the hull girder section modulus. The lever $Z_t$ is to be taken as the vertical distance from the neutral axis to the moulded deck line at side amidships plus the depth of the longitudinal member.

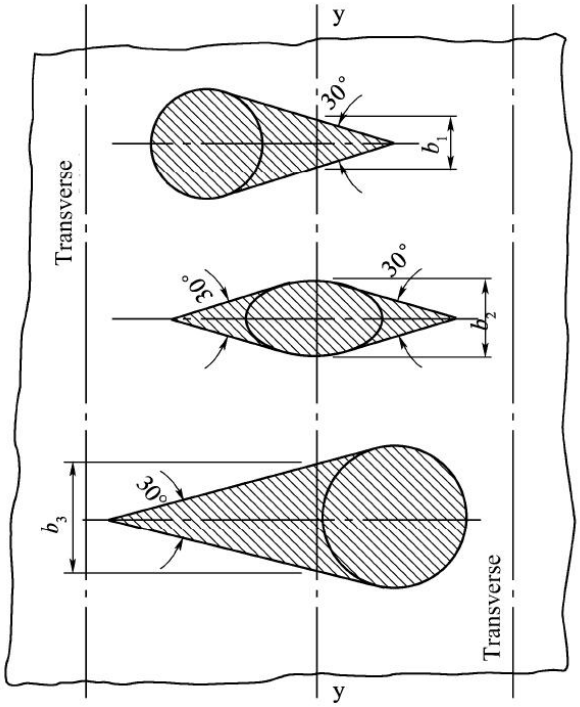
2.2.4.6 Deck openings having a length in the fore-and-aft direction exceeding 2.5 m or a breadth exceeding 1.2 m or 0.04$B$ (whichever is the lesser) or scallops where scallop-welding is applied are to be deducted from the sectional areas used in the calculation of the hull girder section modulus.

2.2.4.7 Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) smaller than those stated in 2.2.4.6 above need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, provided that the sum $b_c$ of their breadths or shadow area breadths (The shadow area will be obtained by drawing two tangent lines with an opening angle of 30°, as shown in Figure 2.2.4.7) in one transverse section complies with the following or that the section modulus at deck or bottom is not reduced by more than 3%:

$$b_c \leqslant 0.06(B_1 - \Sigma b)$$

where: $B_1$ — breadth of ship at section considered, in m;

$\Sigma b$ — sum of breadths of deductible openings at section considered in accordance with 2.2.4.6 of this Section, in m.




Sum of breadths of small openings at *y*-*y* section is to be $b_c = b_1 + b_2 + b_3$

**Figure 2.2.4.7**

2.2.4.8 Openings in longitudinals or longitudinal girders (such as lightening holes, freeing ports, single scallops in way of welds) need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, if their depth does not exceed 25% of the web depth (with a maximum depth of 75 mm for scallops).

### 2.2.5 Hull girder bending strength

2.2.5.1 The minimum midship section modulus $W_0$[1] at deck and keel is not to be less than that obtained from the following formula:

$$W_0 = CL^2B\,(C_b+0.7)K \qquad \text{cm}^3$$

where: $C$ — coefficient[2], to be taken in accordance with 2.2.3.1 of this Section;

$C_b$ — the same as that in 2.2.3.1 of this Section;

$L$ — length of ship, in m;

$B$ — breadth of ship, in m;

$K$ — material factor.

Scantlings of all continuous longitudinal members of the hull girder based on the minimum midship section modulus $W_o$ are to be maintained within 0.4$L$ amidships. However, in special

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[1] The requirements for the minimum midship section modulus are applicable to ships navigating in the unrestriction areas, and may not be applicable to ships with unconventional type or design (e.g. ships with unconventional scale ratio and/or weight distribution). Special consideration is to be given to such ships.

[2] For ships in service, $C$ is 0.9 times the value calculated in 2.2.3.1.

cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4$L$ amidships, bearing in mind the desire not to inhibit the vessel's loading flexibility. In ships where part of the longitudinal strength material in the deck or bottom area are forming boundaries of tanks for oil cargoes or ballast water and such tanks are provided with an effective corrosion protection system, certain reductions in the scantlings of these boundaries are allowed. These reductions, however, are in no case to reduce the minimum hull girder section modulus for a new ship by more than 5%.

2.2.5.2 The moment of inertia of midship section about the horizontal neutral axis $I$ is not to be less than that obtained from the following formula:

$$I = 3W_0L/K \qquad \text{cm}^4$$

where: $W_0$ — the minimum midship section modulus, in cm³, calculated in accordance with 2.2.5.1 of this Section;

$L$ — length of ship, in m;

$K$ — material factor.

2.2.5.3 The hull girder bending strength outside 0.4$L$ amidships is to comply with the requirements of 2.2.5.4 of this Section and also the following requirements:

(1) As a minimum, hull girder bending strength checks are to be carried out at the following locations:

— in way of the forward end of the engine room;

— in way of the forward end of the foremost cargo hold;

— at any locations where there are significant changes in hull cross-section;

— at any locations where there are changes in the framing system.

(2) Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

(3) Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

(4) For ships with large deck openings such as container ships, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

2.2.5.4 The designer is to provide permissible hogging and sagging still water bending moments $\overline{M}_s\,(+)$ and $\overline{M}_s\,(-)$ of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

(1) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are to cover the most severe hogging and sagging design still water bending moments calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.

(2) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{M}_s\,(+)_{\max} = \overline{M} - M_W\,(+) \qquad \text{kN·m}$$

$$\overline{M}_s\,(-)_{\min} = -\overline{M} - M_W\,(-) \qquad \text{kN·m}$$

where: $M_W$ — wave bending moment, see 2.2.3.1 of this Section;

$\overline{M}$ — combined permissible bending moment, in kN · m, to be taken as one of the values obtained from the following formulae, whichever is the lesser:

$$\overline{M} = F_d W_d [\sigma] \times 10^{-3} \quad \text{kN·m}$$

$$\overline{M} = F_b W_b [\sigma] \times 10^{-3} \quad \text{kN·m}$$

where: $F_d$, $F_b$ — determined in accordance with 2.2.5.6(1);

$W_d$ — section modulus at deck, in $cm^3$;

$W_b$ — section modulus at keel, in $cm^3$;

Permissible bending stress of hull girder $[\sigma]$[3] is determined in accordance with the following requirements:

$[\sigma] = 175/K$, in $N/mm^2$, for 0.4 $L$ amidships;

$[\sigma] = 125/K$, in $N/mm^2$, for 0.1 $L$ from the ship's ends;

for other areas, to be obtained by linear interpolation, where $K$ is material factor.

2.2.5.5 Longitudinal bending stress is to be calculated in accordance with the following formula:

$$\sigma = \frac{\left|\overline{M}_s + M_W\right|}{W_c} \times 10^3 \quad \text{N/mm}^2$$

where: $\overline{M}_s$ — permissible still water bending moment, in kN·m, see 2.2.5.4 of this Section;

$M_W$ — wave bending moment, in kN·m, calculated in accordance with 2.2.3.1 of this Section;

$W_c$ — hull girder section modulus at the point considered, in $cm^3$.

2.2.5.6 The reduction factor of scantlings of local members is to comply with the following:

(1) Where the maximum longitudinal bending stresses at deck and keel are less than the permissible bending stress $[\sigma]$, appropriate reduction factors $F_d$ and $F_b$ may be taken to reduce the scantlings of local member provided the following conditions are met:

$$F_d \geq \frac{\sigma_d}{[\sigma]}$$

$$F_b \geq \frac{\sigma_b}{[\sigma]}$$

where: $\sigma_d$ — longitudinal bending stress at deck, in $N/mm^2$;

$\sigma_b$ — longitudinal bending stress at keel, in $N/mm^2$;

$[\sigma]$ — permissible bending stress, see 2.2.5.4(2) of this Section.

In calculation of the thickness of shell plating $t_1$ and deck $t_1$, reduction factor $F_d$ may be calculated based on sagging bending moment and $F_b$ may be calculated based on the hogging bending moment.

For shell plating and deck, reduction factors $F_d$ and $F_b$ are not to be less than 0.67; for framing, reduction factors $F_d$ and $F_b$ are not to be less than 0.75.

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[3] The permissible bending stress of the hull girder beyond the 0.4 $L$ amidships is generally to comply with the requirements of 2.2.5.4(2).

(2) For ships less than 65 m in length, 1 is to be taken for both $F_d$ and $F_b$.

(3) For containerships of 90 m in length and over, see Section 2 of Chapter 7 for the longitudinal bending stress and permissible bending stress in calculation of $F_d$ and $F_b$.

2.2.5.7 Where higher tensile steel is used in some portions of hull, the vertical extent of application of the higher tensile steel is not to be less than:

Where higher tensile steel is applied to the strength deck, the region $y_1$ $(1 - K/F_d)$ below the deck line is to be made of higher tensile steel; where applied to the bottom, the region $y_2$ $(1 - K/F_b)$ above the keel is to be made of higher tensile steel. $y_1$ and $y_2$ are the vertical distances from the neutral axis to the deck line at side and to the plate keel respectively, in m, as shown in Figure 2.2.5.7. $K$ is material factor, $F_d$ and $F_b$ are as defined in 2.2.5.6 above.

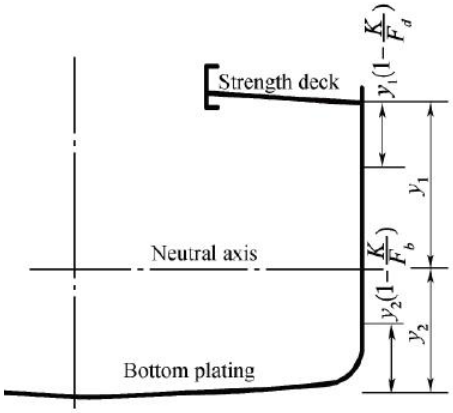



**Figure 2.2.5.7**

2.2.5.8 Where higher tensile steel is used amidships and low carbon steel at the ends of the ship, the region in which higher tensile steel is used is to be extended to the points where the thickness required for low carbon steel is equal to that of the higher tensile steel (see Figure 2.2.5.8).

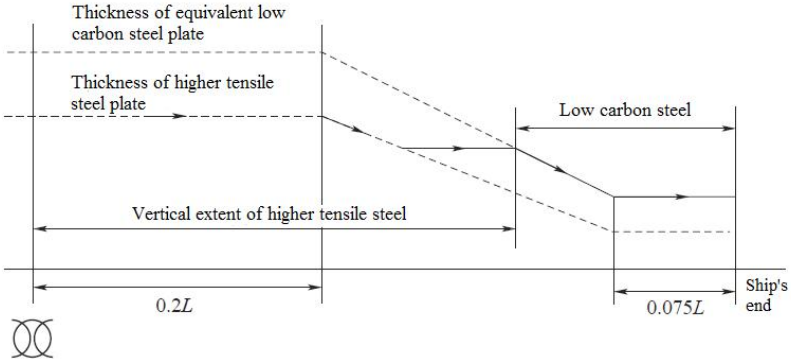



**Figure 2.2.5.8**

2.2.5.9 Where higher tensile steel is applied to strength deck structure, corresponding higher tensile steel is usually to be applied to the continuous members (e.g. stiffening members of hatch coamings and deck openings) welded to strength deck.

### 2.2.6 Hull girder shearing strength

2.2.6.1 Design still water shear force

(1) Under different loading conditions, the design still water shear force at each transverse section along the ship's length is to meet the following conditions:

$$F_s(+) \leqslant \overline{F}_s(+)$$

$$|F_s(-)| \leqslant |\overline{F}_s(-)|$$

where: $F_s$ — design still water shear force under the conditions considered, in kN;

$\overline{F}_s$ — permissible still water shear force, in kN, calculated in accordance with 2.2.6.2.

(2) For type 1 and type 2 hull sections as shown in Table 2.2.6.2, the still water shear force $F_s$ at transverse bulkhead is to be corrected in respect to alternate or significantly non-homogeneous hold loading conditions. The correction of shear force is as shown in Figure 2.2.6.1. The values $N_k$ and $N_m$ of shear force correction are to be calculated in accordance with the following formulae respectively:

$$N_k = F|F_{sA} - F_{sB}| \quad \text{kN}$$

$$N_m = F|F_{sA} - F_{sC}| \quad \text{kN}$$

where: $F_{sA}$, $F_{sB}$, $F_{sC}$ — shear force in kN, obtained by calculation based on hull girder at transverse bulkheads $A$, $B$ and $C$ respectively;

$F$ — correction factor of still water shear force, calculated in accordance with the following formula:

$$F = \frac{B_0}{2.2(B + l_H)}$$

where: $B_0$ — average breadth of the flat part of inner bottom of the hold considered, in m;

$B$ — breadth of ship, in m;

$l_H$ — length of hold, in m.

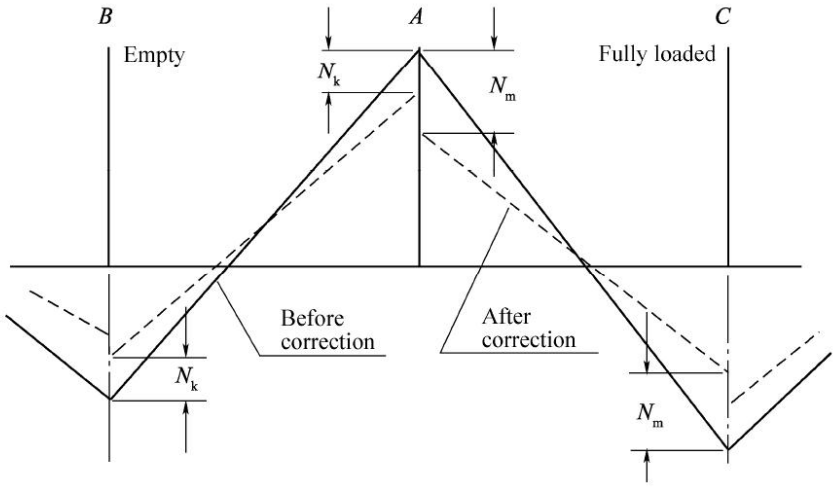



**Figure 2.2.6.1**

2.2.6.2 The designer is to provide permissible still water shear forces $\overline{F}_s(+)$ and $\overline{F}_s(-)$ of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

(1) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are to cover the most severe positive and negative design still water shear forces calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.

(2) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{F}_s(+)_{\max} = [\tau]\ \frac{I\delta}{S} \times 10^{-2}\ -F_w(+)\quad \text{kN}$$

$$\overline{F}_s(-)_{\min} = -[\tau]\ \frac{I\delta}{S} \times 10^{-2}\ -F_w(-)\quad \text{kN}$$

where: $F_w$ — wave shear force, in kN, calculated in accordance with 2.2.3.2;

$I$ — moment of inertia about the horizontal neutral axis at the transverse section under consideration, in $cm^4$;

$S$ — static moment, in $cm^3$, about the horizontal neutral axis, of the area of the effective longitudinal members above the horizontal neutral axis, taken at the transverse section under consideration;

Permissible shearing stress $[\tau] = 110/K$, in $N/mm^2$, where $K$ is material factor;

$\delta$ — the lesser of $\delta_1$ and $\delta_2$, calculated in accordance with the following formulae:

$$\delta_1 = \frac{t_1}{f_1 + m_1}$$

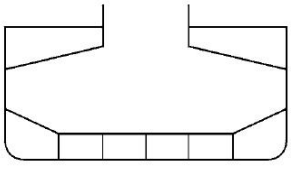
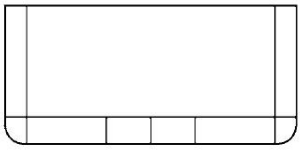
$$\delta_2 = \frac{t_2}{f_2 + m_2}$$

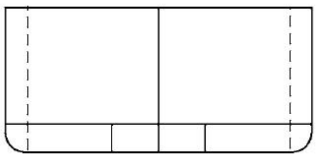
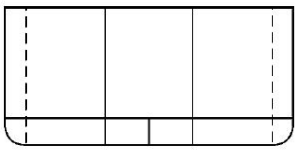
$t_1$ — thickness (the total thickness of inner and outer plating for double hull-skin ship) of side shell at the horizontal neutral axis of the section under consideration, in mm;

$t_2$ — thickness of longitudinal bulkhead plating at the horizontal neutral axis of the section under consideration, in mm;

$f_1, f_2, m_1$, and $m_2$ — factors, see Table 2.2.6.2.

**Factors $f_1$, $f_2$, $m_1$ and $m_2$** **Table 2.2.6.2**

| No. | Hull configuration | Factor $f_i$ | Factor $m_i$ |
|---|---|---|---|
| 1 |  | $f_1 = 0.5$ | $m_1 = 0$ |
| 2 |  | $f_1 = 0.5$ | $m_1 = 0$ |

| | | | |
|---|---|---|---|
| 3 |  | $f_1 = 0.261 + 0.058\, A_1 / A_2$<br>$f_2 = 0.478 - 0.116\, A_1 / A_2$ | $m_1 = 0.5\, m_2$<br>$m_2 = 0.5(0.1 + \gamma)$ |
| 4 |  | $f_1 = 0.154 + 0.08\, A_1 / A_2$<br>$f_2 = 0.346 - 0.08\, A_1 / A_2$ | $m_1 = m_2$<br>$m_2 = (0.1 + \gamma)\ \frac{b}{B}$ |

Notes: $A_1$, $A_2$— shear areas of side shell and longitudinal bulkhead plating respectively, in cm$^2$, at one side of the section under consideration. The area for the centreline bulkhead is actual area and not to be reduced for symmetry around the centreline;

$b$ — horizontal distance from longitudinal bulkhead to side shell plating, in m;

$B$ — breadth of ship, in m;

$\gamma$ — for transversely non-homogeneous loading condition, $\gamma$ = 0.15; for transversely homogeneous loading condition, $\gamma$ = 0.

2.2.6.3 For hull configurations not included in Table 2.2.6.2, e.g. ships with three or four longitudinal bulkheads, the shearing stresses at side shell and longitudinal bulkhead plating may be determined by direct calculation.

2.2.6.4 Shearing stress[4]

(1) The shearing stress $\tau$ at side shell is to be calculated in accordance with the following formula:

$$\tau = \frac{\left|\overline{F}_s + F_w\right| S}{I\delta_1} \times 10^2 \quad \text{N/mm}^2$$

where: $\overline{F_s}$ — permissible still water shear force, in kN, see 2.2.6.2 of this Section;

$S$ — static moment, in cm$^3$. Where the point considered is above the horizontal neutral axis, $S$ is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point above the neutral axis. Where the point considered is below the horizontal neutral axis, $S$ is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point below the neutral axis;

$F_w$, $I$ and $\delta_1$ — see 2.2.6.2 of this Section.

(2) Shearing force $\tau$ at longitudinal bulkhead plating is to be calculated in accordance with the following formula:

$$\tau = \frac{\left|\overline{F}_s + F_w\right| S}{I\delta_2} \times 10^2 \quad \text{N/mm}^2$$

where: $\overline{F_s}$, $S$ — see 2.2.6.4 (1) of this Section;

$F_w$, $I$ and $\delta_2$ — see 2.2.6.2 of this Section.

### 2.2.7 Buckling strength

[4] Direct calculation may be used for shear stress subject to approval.

2.2.7.1 For ships of 90 m and over in length, where the plate panels and longitudinals are subject to hull girder bending and shear stresses, the buckling strength is to be checked according to the following requirements.

2.2.7.2 The working stress σ in compression of the plate panels and longitudinals as calculated in 2.2.5.5 of this Section (taken not less than 30/$K$, in N/mm$^2$, where $K$ is material factor) is to comply with the following formula:

$$\sigma \le \frac{1}{\beta}\sigma_c$$

where: $\beta$ = 1, for plating and for web plating of stiffeners (local buckling);

$\beta$ = 1.1, for stiffeners;

$\sigma_c$ — critical buckling stress in compression, calculated according to 2.2.7.6 of this Section.

2.2.7.3 The working shear stress $\tau$ of plate panels as calculated in 2.2.6.4 of this Section is to comply with the following formula:

$$\tau \le \tau_c$$

where: $\tau_c$ — critical buckling stress in shear, calculated according to 2.2.7.7 of this Section.

2.2.7.4 The ideal elastic buckling stresses of the plates are to be obtained from the following formulae:

(1) The ideal elastic buckling stress $\sigma_E$ of the compression plate panel is to be obtained from the following formula:

$$\sigma_E = 0.9K_cE\left(\frac{t_b}{1000s}\right)^2 \qquad \text{N/mm}^2$$

where: $E$ — modulus of elasticity of material, in N/mm$^2$;

$s$ — shorter side of plate panel, in m;

$t_b$ — net thickness, in mm, of plating, considering standard deductions equal to the values given in Table 2.2.7.4;

$K_c$ – coefficient, calculated according to the following:

$K_c = \dfrac{8.4}{\psi + 1.1}$ for plating with longitudinal stiffeners (parallel to compressive stress);

$K_c = C\left[1+\left(\dfrac{S}{l}\right)^2\right]^2 \dfrac{2.1}{\psi + 1.1}$ for plating with transverse stiffeners (perpendicular to compressive stress);

where:

$l$ — longer side of plate panel, in m;

$C$ = 1.3 when plating stiffened by floors or deep girders;

$C$ = 1.21 when stiffeners are angles or T-sections;

$C$ = 1.10 when stiffeners are bulb flats;

$C$ = 1.05 when stiffeners are flat bars;

$\psi$ — ratio between smallest and largest compressive stress, $0 \le \psi \le 1$ (see Figure 2.2.7.4).

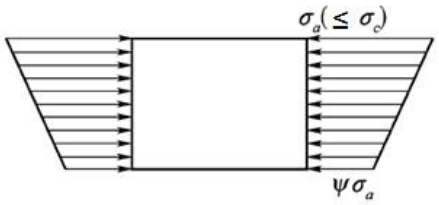



**Figure 2.2.7.4**

(2) The ideal elastic buckling stress $\tau_E$ in shear of plate panels subjected to shearing forces is to be obtained from the following formula:

$$\tau_E = 0.9K_t E\left(\frac{t_b}{1000s}\right)^2 \quad \text{N/mm}^2$$

where: $K_t = 5.34 + 4\left(\frac{s}{l}\right)^2$;

for $E$, $t_b$, $s$ and $l$, see (1) above.

**Standard Deduction of Thickness** **Table 2.2.7.4**

| Structure | Standard deduction (mm) | Limit values min-max (mm) |
|---|---|---|
| Compartments carrying dry bulk cargoes:<br>One side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25º to the horizontal line. | 0.05 $t$ | 0.5 ~ 1 |
| One side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25º to the horizontal line;<br>Two side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25º to the horizontal line. | 0.10 $t$ | 2 ~ 3 |
| Two side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25º to the horizontal line. | 0.15 $t$ | 2 ~ 4 |

Note: $t$ is the designed thickness of plating, in mm.

2.2.7.5 The ideal elastic buckling stresses of longitudinals are to be obtained from the following formulae:

(1) For the column buckling mode (perpendicular to plane of plating) without rotation of the cross section, the ideal elastic buckling stress $\sigma_E$ of longitudinals is to be obtained from the following formula:

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \quad \text{N/mm}^2$$

where: $I_a$ — moment of inertia, in cm$^4$, of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

$A$ — cross-sectional area, in cm², of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

$l$ — span, in m, of longitudinal.

(2) The ideal elastic buckling stress $\sigma_E$ of longitudinals for the torsional buckling mode is to be obtained from the following formula:

$$\sigma_E = \frac{\pi^2 E I_W}{I_p l^2 \times 10^4}\left(n^2 + \frac{K_B}{n^2}\right) + 0.385 E \frac{I_t}{I_p} \qquad \text{N/mm}^2$$

where: $K_B = \frac{Cl^4}{\pi^4 E I_W} \times 10^6$;

$n$ — number of half waves, given by Table 2.2.7.5:

$I_t$ — St Venant's moment of inertia, in cm⁴, of profile (without plate flange), to be obtained by the following formula:

$I_t = \frac{h_w t_w^3}{3}$ $\times 10^{-4}$, for flat bars;

$I_t = \frac{1}{3}\left[h_w t^3{}_w + b_f t^3{}_f \left(1 - 0.63\frac{t_f}{b_f}\right)\right] \times 10^{-4}$ for flanged profiles;

$I_p$ — polar moment of inertia, in cm⁴, of profile about connection of stiffener to plate:

$I_p = \frac{h^3{}_w t_w}{3}$ $\times 10^{-4}$ for flat bars;

$I_p = (\frac{h^3{}_w t_w}{3} + h_w^2 b_f t_f) \times 10^{-4}$ for flanged profiles;

$I_w$ — sectional moment of inertia, in cm⁶, of profile about connection of stiffener to plate:

$I_w = \frac{h^3{}_w t^3{}_w}{36}$ $\times 10^{-6}$ for flat bars;

$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$ for Tee profiles;

$I_w = \frac{b_f^3 h_w^2}{12\left(b_f + h_w\right)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right]$ $\times 10^{-6}$ for angles and bulb profiles;

where: $l$ — span of longitudinal, in m;

$E$ — modulus of elasticity of material, in N / mm²;

$h_w$ — web height, in mm;

$t_w$ — web thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

$b_f$ — flange width, in mm;

$t_f$ — flange thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section. For bulb profiles the mean thickness of the bulb may be used;

$C$ — spring stiffness exerted by supporting plate panel, obtained by the following formula:

$$C = \frac{K_p E t_p^3}{3s\left(1 + \frac{1.33 K_p h_w t_p^3}{1000 s t_w^3}\right)} \times 10^{-3}$$

$s$ — spacing of profiles, in m;

$t_p$ — panel thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

$K_p = 1 - \eta_P$, not to be taken less than zero. For flanged profiles, $K_p$ need not be taken less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{EP}};$$

$\sigma$ — working pressure in compression, calculated in accordance with 2.2.5.5 of this Section, but not to be taken as less than $30/K$, in N/mm², where $K$ is material factor;

$\sigma_{EP}$ — elastic buckling stress of supporting plate as calculated in 2.2.7.4 of this Section.

**Number of Half Waves** **Table 2.2.7.5**

| | $0 < K_B \leq 4$ | $4 < K_B \leq 36$ | $36 < K_B \leq 144$ | $(n-1)^2\, n^2 < K_B \leq n^2\,(n+1)^2$ |
|---|---|---|---|---|
| $n$ | 1 | 2 | 3 | $n$ |

(3) Web and flange buckling of longitudinals

① For web plate of longitudinals, the ideal elastic buckling stress $\sigma_E$ is to be obtained from the following formula:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \quad \text{N/mm}^2$$

where: $t_w$, $h_w$, $E$ — see (2).

② For flanges on angles and T-sections of longitudinals, buckling is taken care of by the following requirement:

$$\frac{b_f}{t_f} \leq 15$$

where: $b_f$ — flange width, in mm, for angles, half the flange width for T-sections;

$t_f$ — flange thickness, in mm.

2.2.7.6 The critical buckling stress in compression $\sigma_c$ is determined as follows:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where: $R_{eH}$ — yield stress of material, in N/mm²;

$\sigma_E$ — ideal elastic buckling stress, in N/mm², calculated according to 2.2.7.4(1) and 2.2.7.5 of this Section.

2.2.7.7 The critical buckling stress in shear $\tau_c$ is determined as follows:

$$\tau_c = \tau_E \qquad \text{for } \tau_E \leq \frac{\tau_s}{2}$$

$$\tau_c = \tau_s\left(1 - \frac{\tau_s}{4\tau_E}\right) \qquad \text{for } \tau_E > \frac{\tau_s}{2}$$

where: $\tau_s = \frac{R_{eH}}{\sqrt{3}}$;

$R_{eH}$ — yield stress of material, in N/mm$^2$;

$\tau_E$ — ideal elastic buckling stress in shear, in N/mm$^2$, calculated according to 2.2.7.4(2) of this Section.

### 2.2.8 Loading manual and loading instrument

2.2.8.1 On completion of construction of the ship, a Loading Manual is to be formulated in time and submitted by the designer to CCS for approval. CCS Guidelines for Preparation of Loading Manuals may be referred to for formulating the Loading Manual.

2.2.8.2 The ship is to be loaded in accordance with the requirements specified in the Loading Manual to avoid the creation of unacceptable stresses in the hull structures.

2.2.8.3 The Loading Manual is to contain the following:

(1) The loading conditions on which the design of the ship has been based, including curves of permissible still water bending moment and shear force along the length of the ship.

(2) The results of the calculations of still water bending moments and shear forces under various loading conditions and where necessary, limitations due to torsional and lateral loads.

(3) The allowable local loading for local structures (such as hatch covers, decks and double bottom, etc.).

2.2.8.4 Loading instruments are to comply with the following specifications:

(1) A loading instrument is either an analog or a digital instrument, by means of which it can be easily and quickly ascertained that the still water bending moment, shear forces and where applicable, the still water torsional moments and lateral loads at specified read-out points will not exceed the specified permissible values in any loading or ballasting condition.

(2) The loading instrument is generally to be provided with an operation manual.

(3) Single-point loading instruments are not acceptable.

(4) The detailed requirements for loading instruments are referred to Appendix 1 of this Chapter.

2.2.8.5 Those ships complying with one of the following provisions are Category I ships:

(1) Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending as well as torsional and lateral loads are to be considered.

(2) Ships possibly with non-homogeneous loading, where the cargo and ballast may be unevenly distributed. Ships less than 120 m in length, when uneven distribution of cargo and/or ballast is considered in design, belong to Category II.

(3) Chemical tankers and gas carriers.

2.2.8.6 Those ships complying with one of the following provisions are Category II ships:

(1) ships with such arrangements that would allow only a small possibility for variation in the distribution of cargo and ballast, and ships operating on a regular and fixed trading pattern where the loading manual gives sufficient guidance;

(2) ships for which an exception is given under Category I.

2.2.8.7 An approved loading manual is to be supplied to all ships except those of Category II with length less than 90 m of which the deadweight does not exceed 30% of the displacement at the summer load line draft.

2.2.8.8 An approved loading manual is to be supplied to all ships of Category I with 100 m or over in length.

2.2.8.9 Bulk carriers, ore carriers and combination carriers of 150 m or over in length are to be provided with a loading manual and a loading instrument in accordance with the requirements of Section 7, Chapter 8 of this PART.

2.2.8.10 Ships navigating in coastal areas and sheltered areas may not be equipped with loading computer.

2.2.8.11 Conditions for approval of loading manuals:

(1) The approval of the loading manual is to be based on the final data of the ship. The manual is to include the design loading and ballasting conditions upon which the approved scantlings of hull structures are approved.

(2) In case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

(3) The loading manual must be prepared in a language understood by the users.

2.2.8.12 Conditions for approval of loading instruments:

(1) The following are to be included in loading instruments and approved:

① Confirmation of type approval, if any;

② Confirming that the final data of the ship have been used;

③ Confirmation of the number and positions of read-out points;

④ Confirmation of relevant limits for all read-out points;

⑤ Checking of proper installation and operation of the instrument on board, in accordance with the approved test report of loading calculation, and that a copy of the operation manual is available.

(2) In case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and reapproved.

(3) The operation manual and the instrument output must be prepared in a language understood by the users.

(4) The operation of the loading instruments is to be verified upon installation. It is to be checked that the operation manual and the approved test loading conditions are available on board.

### 2.2.9 Direct calculation of wave loads

2.2.9.1 The direct calculation of wave loads is to be based on the following assumptions:

(1) The calculation software is to be based on the three-dimensional linear or non-linear wave theory and subject to approval.

(2) For the ships navigating in coastal areas, wave statistics based on the marine environment of the North Atlantic, as given in IACS REC34, are used in the prediction of wave loads. For the ships navigating in sheltered areas, wave statistics based on the navigation areas are used in the prediction of wave loads. If the wave statistical data of navigation area is not limited to one type, the most serious one is to be selected for calculation.

(3) The requirements for wave frequencies, wave heading angles and the considered ship speed are given in Section 5, Chapter 1 of this PART.

(4) The wave spectrum and energy spread function under consideration are given in Section 5, Chapter 1 of this PART.

(5) The long-term prediction results at the probability level of $10^{-8}$ are taken as calculation results.

2.2.9.2 The hydrodynamic models used in calculation are to comply with the following requirements:

(1) The mass model is to correctly reflect the mass and its distribution of the real ship, ensuring that the error between mass of the model and that of the real ship is not greater than 0.1% and that the error between position of center of gravity of the model and that of the real ship is not greater than 0.1%$L$.

(2) The model of wetted surface is to be sufficiently refined for an accurate simulation of the shape of the real ship from the hydrodynamic perspective. The error between displacement of the model and that of the real ship is not to be greater than 0.1%, the error between position of center of buoyancy of the model and that of the real ship is not to be greater than 0.1% $L$, and the number of elements is generally not to be less than 2,000.

2.2.9.3 The wave bending moments and shear forces obtained by the linear wave theory are to be subject to non-linear correction as follows:

(1) The hogging wave bending moment $M_W$ (+) and the sagging wave bending moment $M_W$ (–) are to be calculated by the following formulas:

$$M_W(+) = Mf_{nl\text{-}h}M_{W,cal} \quad \text{kN·m}$$
$$M_W(-) = -Mf_{nl\text{-}s}M_{W,cal} \quad \text{kN·m}$$

where: $M_{W,\,cal}$ — maximum vertical wave bending moment between 0.4$L$ and 0.6$L$, obtained by direct calculation based on linear wave theory;

$M$ — distribution factor of bending moment along ship's length, see Figure 2.2.3.1 of this Chapter;

$f_{nl-h}$ , $f_{nl-s}$ — non-linear correction factor, determined by the following formulas:

$$f_{nl-h} = \frac{190C_b}{95C_b + 55(C_b + 0.7)}$$
$$f_{nl\text{-}s} = \frac{110(C_b + 0.7)}{95C_b + 55(C_b + 0.7)}$$

where: $C_b$ — block coefficient, taken not less than 0.6.

(2) The hogging wave shear force $F_W$ (+) and the sagging wave shear force $F_W$ (−) are to be calculated by the following formulas:

$$F_W(+) = F_{nl,1}F_{WV,\,\max} \quad \text{kN}$$
$$F_W(-) = -F_{nl,2}F_{WV,\,\max} \quad \text{kN}$$

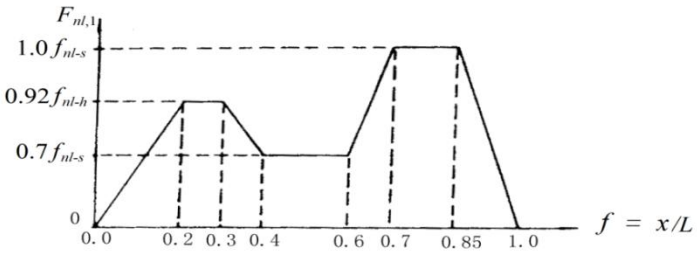
where: $F_{nl,1}$, $F_{nl,2}$ — distribution factors taking non-linear correction into account, see Figures 2.2.9.3(1) and 2.2.9.3(2) respectively. For $f_{nl-h}$, $f_{nl-s}$ in the Figures, see (1) above.

$F_{WV,\,\max}$ is to be calculated by the following formula:

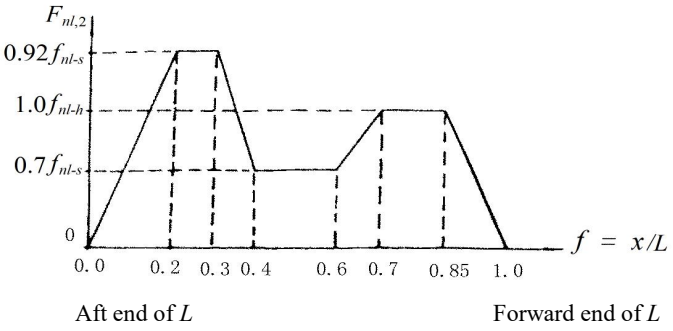
$$F_{WV,\max} = \max\left(\frac{\max\left|F_{WV,CAL,A}\right|}{0.92}, \frac{\max\left|F_{WV,CAL,F}\right|}{1.0}\right) \text{kN}$$

where: $F_{WV,\,CAL,\,A}$ — wave shear force, in kN, directly calculated for sections with $x/L < 0.5$;

$F_{WV,\,CAL,\,F}$ — wave shear force, in kN, directly calculated for sections with $x/L \geq 0.5$.




**Figures 2.2.9.3(1) Distribution of Factor $F_{nl,1}$ along Ship's Length**




**Figures 2.2.9.3(2) Distribution of Factor $F_{nl,2}$ along Ship's Length**

2.2.9.4 For specific ships, e.g. engineering ships which need to carry out short-term operation, short-term prediction of wave loads is to be used to determine wave loads in the operating condition based on the most severe short-term sea state provided by the designer. The period of short-term prediction is generally taken as 3 hours or the operating hours provided by the designer, whichever is greater.

# Section 3 SHELL PLATING

### 2.3.1 Bottom shell

2.3.1.1 Bottom shell means the shell plating between the plate keel and the bilge strake.

2.3.1.2 In a ship with transverse bottom framing, the thickness $t$ of bottom shell plating within 0.4$L$ amidships is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$ — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

$d$ — draught, in m;

$L$ — length of ship, in m, to be taken as not greater than 200 m;

$F_b$ — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1+\frac{s^2}{S^2}$, where $S$ is spacing of girders or keelsons, in m;

$h_1$ = 0.26 $C$, to be taken as not greater than 0.2 $d$;

$C$ — coefficient, see 2.2.3.1 of Section 2;

$K$ — material factor.

2.3.1.3 In a ship with longitudinal bottom framing, the thickness $t$ of bottom shell plating within 0.4$L$ amidships is not to be less than the values obtained from the following:

$$t_1 = 0.043s(L+230)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.6s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

$d$ — draught, in m;

$L$ — length of ship, in m, to be taken as not greater than 190 m;

$F_b$, $h_1$ — see 2.3.1.2 of this Section;

$K$ — material factor.

2.3.1.4 The thickness $t$ of bottom shell plating within the regions of 0.075$L$ from the ship's ends is not to be less than that obtained from the following formula:

$$t = (0.035L + 6)\sqrt{\frac{sK}{0.7}} \quad \text{mm}$$

where: $L$ — length of ship, in m, $L$ need not be taken as greater than 300 m;

$s$ — spacing of frames or longitudinals, in m, to be taken as not less than 0.7;

$K$ — material factor.

2.3.1.5 The thickness of bottom shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L + 6)\sqrt{K} \quad \text{mm}$$

where: $L$ — length of ship, in m;

$K$ — material factor.

The thickness of bottom shell plating beyond 0.4$L$ amidships is to be tapered gradually to the end thickness of bottom shell plating.

2.3.1.6 The thickness of bottom shell plating at fore end is, in addition, to comply with the relevant requirements of Section 15 of this Chapter.

### 2.3.2 Plate keel

2.3.2.1 The width $b$ of the plate keel is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \quad \text{mm}$$

where: $L$ — length of ship, in m.

The width of the plate keel need not be greater than 1,800 mm, and is to be maintained over the whole length of the ship.

2.3.2.2 The thickness of the plate keel is not to be less than that of the bottom shell plating calculated according to 2.3.1 of this Section in accordance with its structural configuration plus 2.0 mm nor less than that of the adjacent bottom shell plating.

### 2.3.3 Bilge strake

2.3.3.1 Where the bilge is framed transversely, the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.2 of this Section, and where the bilge is framed longitudinally,

the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.3 of this Section.

2.3.3.2 Where both the bottom and side shells are framed longitudinally and the bilge longitudinals are omitted, and where transverse strength members or corresponding bilge brackets are fitted in accordance with the requirements of 2.6.15.5 of this Chapter, the thickness of the bilge strake is neither to be less than $\frac{rF_b}{165K_L}$ ($r$ being the radius of bilge, in mm, $K$ being material factor and $F_b$ being reduction factor of bottom), nor to be less than that of the adjacent bottom plating.

### 2.3.4 Side shell plating

2.3.4.1 Side shell plating means the shell plating between the bilge strake and the sheer strake.

2.3.4.2 Where the side shell is framed transversely, the thickness $t$ of side shell plating within $0.4L$ amidships is to be as follows:

(1) The thickness $t$ of side shell plating above $\frac{3}{4}D$ from base is not to be less than the following:

$$t_1 = 0.073sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness $t$ of side shell plating within $\frac{1}{2}D$, the centre point of which is $0.5D$ from base, is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_m}{K}} \quad \text{mm}$$

$$t_2 = 5.1s\sqrt{(d+h_2)K} \quad \text{mm}$$

(3) The thickness $t$ of side shell plating below $\frac{1}{4}D$ from base is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$ — spacing of frames, in m; to be taken as not less than the standard spacing of frames;

$L$ — length of ship, in m, $L$ need not be taken as greater than 190 m;

$d$ — draught, in m;

$F_d$, $F_b$— reduction factors, see 2.2.5.6 of this Chapter;

$F_m$ — reduction factors, to be taken as $F_d$ or $F_b$, whichever is the greater;

$E = 1+\frac{s^2}{S^2}$, where $S$ is the spacing of side stringers, in m;

$h_2 = 0.5C$, to be taken as not greater than $0.36d$;

$h_1$, $C$ — see 2.3.1.2 of this Section;

$K$ — material factor.

(4) In calculation of $t_1$, except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor $K$ may be taken as 1.

2.3.4.3 Where the side shell is framed longitudinally, the thickness $t$ of side shell plating within 0.4$L$ amidships is to be as follows:

(1) The thickness $t$ of side shell plating above $\frac{1}{2}D$ from base is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness $t$ of side shell plating below $\frac{1}{4}D$ from base is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.4s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

$L$ — length of ship, in m, $L$ need not be taken as greater than 190 m;

$d$ — draught, in m;

$F_d$, $F_b$— reduction factors, see 2.2.5.6 of this Chapter;

$h_1$ — see 2.3.1.2 of this Section;

$h_2$ — see 2.3.4.2 of this Section;

$K$ — material factor.

(3) The thickness $t$ of side shell plating between $\frac{1}{4}D$ and $\frac{1}{2}D$ from base is to be obtained by interpolation between the values of $t_2$ in (1), (2) above, but not less than $t_1$ in (2) above.

(4) For the calculation of $t_1$, except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor $K$ may be taken as 1.

2.3.4.4 The thickness of side shell plating within 0.075$L$ from the ship's ends is to comply with the requirements of 2.3.1.4 of this Section.

2.3.4.5 The thickness of side shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L + 6)\sqrt{K} \quad \text{mm}$$

where: $L$ — length of ship, in m;

$K$— material factor.

The thickness of side shell plating beyond 0.4$L$ amidships is to be tapered gradually to the end thickness of side shell plating.

### 2.3.5 Sheer strake

2.3.5.1 The width of the sheer strake is not to be less than:

$b = 800 + 5L$ mm, but need not be greater than 1,800 mm

where: $L$ — length of ship, in m.

2.3.5.2 Where the side shell is framed transversely, the thickness $t$ of the sheer strake within 0.4$L$ amidships is not to be less than the following:

$$t_1 = 0.085sE^{-1}\,(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

$L$ — length of ship, in m;

$L_1$ = $L$, in m, need not be taken as greater than 200 m;

$F_d$, $E$ — see 2.3.4.2 of this Section;

$K$ — material factor.

2.3.5.3 Where the side shell is framed longitudinally, the thickness $t$ of the sheer strake within 0.4$L$ amidships is not to be less than the following:

$$t_1 = 0.06s(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

$L$ — length of ship, in m;

$L_1$ = $L$ , in m, need not be taken as greater than 200 m in calculation;

$F_d$ — reduction factors, see 2.2.5.6 of this Chapter;

$K$ — material factor.

2.3.5.4 The thickness of sheer strake within 0.4$L$ amidships is in any case not to be less than 0.8 times that of the stringer plate of the strength deck, nor less than that of adjacent side shell plating, and may be gradually tapered to the end thickness of the side shell plating.

2.3.5.5 Where the sheer strake is connected to the stringer plate by welding, the upper edge of the sheer strake is to be dressed smooth, and any fittings welded to the top of the sheer strake within 0.5$L$ amidships are to be avoided. Scupper openings are not to be cut in the sheer strake which is protruded above the deck within 0.5$L$ amidships or in way of breaks of superstructures.

Where a rounded sheer strake is adopted, the radius is not to be less than 15 times the thickness of the plate. The thickness of rounded sheer strake is to be at least equal to that of deck plating. Effective measures are to be taken to maintain the required properties of material after shaping. Deck fittings welded directly to the rounded sheer strake within 0.5$L$ amidships are to be avoided, wherever possible.

### 2.3.6 Local strengthening

2.3.6.1 The thickness of shell plates connected to the stern frame or fitted in way of the shaft bossing in single screw ships and in way of the palms of propeller struts in multi-screw ships, is neither to be less than 1.5 times the thickness of shell plating at ends, nor to be less than the thickness of the shell plating amidships.

2.3.6.2 The shell plating in way of hawse pipe and one plate below are to be increased in thickness or to be fitted with doubler plates. The outlet of hawse pipe is to have adequate corner radius. It is recommended that the corner radius of chafing lips made of steel plate or cast steel be not less than 12 times the diameter of anchor chain.

### 2.3.7 Openings in shell plating

2.3.7.1 Openings cut in the turn of the bilge strake within 0.5*L* amidships are to be avoided as far as possible, but if necessary, the openings are to be elliptical with the major axis arranged in the fore and aft direction.

2.3.7.2 In general, compensation will not be required for circular openings in the sheer strake which are clear of the gunwale and the deck openings outside the line of hatchways and whose depth does not exceed 20% of that of the sheer strake or 380 mm, whichever is the lesser. Circular openings in sheer strake are to be kept well clear of the ends of superstructures. Openings cut in a rounded gunwale are not allowed.

2.3.7.3 Sea inlets and other openings are to have well rounded corners. The thickness of sea inlet box plating and its steel grade are not to be lower than the adjacent shell. For ships of 90 m or over in length, this thickness is not to be less than 12 mm, but need not exceed 25 mm.

2.3.7.4 Cargo door openings are to have well rounded corners, and are to be kept clear of the ends of superstructures and the deck openings outside the line of hatchways. Such openings within 0.5*L* amidships are to be fully compensated by insert plates or doubler plates with a sufficient length in the fore and aft direction.

### 2.3.8 Bilge keels

2.3.8.1 Where bilge keels are fitted, they are to be attached to a continuous flat bar which may be welded to the shell. All butts of bilge keels, flat bars and shell plating are to be properly shifted from one another. Bilge keels and flat bars are not to be interrupted abruptly, but to be gradually tapered at their ends and terminated on a suitably stiffened panel.

## Section 4 DECKS

### 2.4.1 General requirements

2.4.1.1 This Section applies to all decks with longitudinal or transverse framing.

2.4.1.2 Where the platform decks terminate within 0.4*L* amidships, horizontal brackets are to be provided at their ends and are to extend over a suitable length.

### 2.4.2 Strength deck

2.4.2.1 The thickness $t$ of strength deck plating outside the line of openings within 0.4*L* amidships is, in addition to complying with the requirements for midship section modulus, not to be less than the following:

(1) For transverse framing:

$$t_1 = 0.085sE^{-1}(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

$L$ — length of ship, in m;

$L_1$ = $L$, in m, need not be taken as greater than 200 m in calculation;

$F_d$ — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1 + \frac{s^2}{S^2}$, where $S$ is spacing of deck longitudinals;

$K$ — material factor.

(2) For longitudinal framing:

$$t_1 = 0.06s(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

$L$ — length of ship, in m;

$L_1$ = $L$ in m, need not be taken as greater than 200 m;

$F_d$ — reduction factor, see 2.2.5.6 of this Chapter;

$K$ — material factor.

2.4.2.2 The thickness $t$ of strength deck plating inside the line of openings and within 0.075$L$ from the ship's ends, irrespective of longitudinal or transverse framing, is not to be less than that obtained from the following formula:

$$t = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

$L$ — length of ship, in m;

$K$ — material factor.

2.4.2.3 The minimum thickness $t$ of the strength deck plating (including deck plating at ends) is not to be less than 6 mm.

2.4.2.4 Where the long bridge deck within 0.5$L$ amidships is regarded as the strength deck, the midship section modulus and the minimum thickness are to comply with the requirements of 2.2.5 and 2.4.2.1 of this Chapter.

2.4.2.5 The thickness of strength deck plating is to be maintained for 0.4$L$ amidships and is to be gradually tapered to the end thickness.

2.4.2.6 Where the strength deck at the ship's fore end is not protected by a forecastle, the plate thickness of strength deck forward of 0.15$L$ from the fore perpendicular is to meet the requirements for forecastle deck.

### 2.4.3 Stringer plates

2.4.3.1 The thickness of strength deck stringer plates is not to be less than the thickness of strength deck plating. The breadth of strength deck stringer plates within 0.4$L$ amidships is to comply with the relevant requirements of Section 3, Chapter 1 of this PART. The breadth of strength deck stringer plates at ends of the ship is not to be less than 65% of that amidships.

### 2.4.4 Deck openings

2.4.4.1 Where the corners of engine/boiler room or hatch openings in the strength deck are parabolic or elliptical, insert plates are not required, but the requirements as shown by Figure 2.4.4.1 are to be complied with.

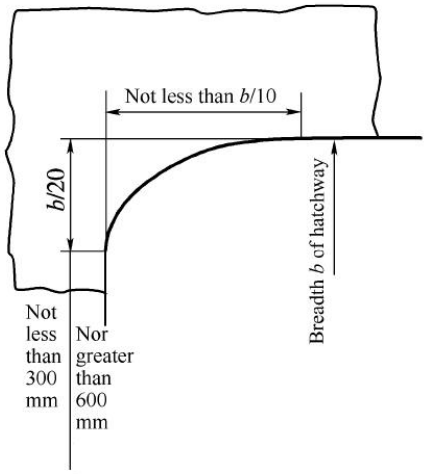



**Figure 2.4.4.1**

2.4.4.2 Where the corners of engine/boiler room or hatch openings in the strength deck are rounded, insert plates are required, and the radius of the rounded corner is not to be less than 1/20 of the breadth of the opening, but not less than 1/10 provided that deck girders are not fitted in way of the hatch coamings. Rounded corners are to have a minimum radius of 300 mm if the deck plating extends inside the coaming, or 150 mm if the coamings are welded to the inner edge of the deck plating in the form of a spigot.

The extension of the insert plates is to be as shown in Figure 2.4.4.2 ($R$ is the radius of hatch corners, $e$ is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing). The butt of the insert plate is to be kept well clear of the butt in coaming and the fillet welds of deck framing. The thickness of the insert plate is to be 4 mm greater than the thickness of strength deck framing. If the thickness or extension of the insert plate can not meet above requirements, direct calculation covering yield, buckling and fatigue is to be adopted for verification.

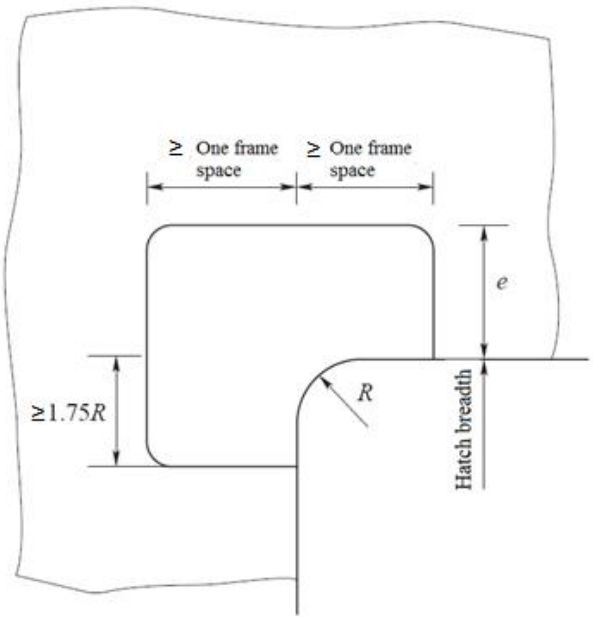



**Figure 2.4.4.2**

2.4.4.3 Openings in the strength deck outside the line of hatchways are to be kept to a minimum and are to be arranged clear of hatch corners. The corners of all openings are to be well rounded and with the edges smoothed.

Openings in the strength deck between midship bridge or deckhouse end bulkheads and hatches are to be avoided so far as possible.

2.4.4.4 Compensation is not required for openings in the strength deck outside the line of hatchways and situated within 0.5*L* amidships provided that they comply with the provisions of 2.2.4.7 of this Chapter. Edge reinforcement will not be required for:

(1) elliptical openings having their major axis in the fore and aft direction and an aspect ratio not less than 2;

(2) openings of other shapes provided that it has been shown by suitable tests that the stress concentration factor does not exceed 2 for low carbon steel and 1.5 for higher tensile steel.

2.4.4.5 Where the openings in the strength deck within 0.5*L* amidships and outside the line of hatchways do not comply with the provisions of 2.2.4.7 of this Chapter, compensation is required. Compensation is normally arranged by increasing the deck plate thickness. Where the openings do not comply with the provisions of 2.4.4.4(1) or (2) of this Section, the edge reinforcement in the form of a spigot as shown in Figure 2.4.4.5 is to be adopted, or alternative arrangements will be considered. Where a spigot is adopted, the sectional area *A* of the ring plate is not to be less than that obtained from the following formula:

$$A = 0.5rt \quad \text{mm}^2$$

where: $r$ — radius of opening, in mm, and to be taken as the half breadth of the openings for elliptical openings;

$t$ — thickness of deck plating, in mm.

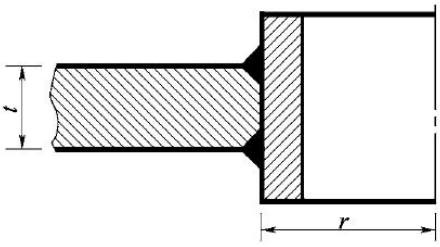



**Figure 2.4.4.5**

2.4.4.6 Lower deck openings are to comply with the following requirements:

(1) Inserts are required for machinery spaces and cargo hatch opening corners on second tier decks, and the thickness of inserts is to be 2.5 mm greater than the deck thickness. Insert plates will not generally be required for hatch corners on third tier decks and decks below (including platform decks).

(2) Openings outside the line of hatchways are to be as far as practicable kept clear of hatch corners and other areas of high stress. The provisions of 2.4.4.4 and 2.4.4.5 of this Section are generally also applicable to openings in lower decks, but compensation will not be required unless the total breadth of openings (see shadow areas as shown in Figure 2.2.4.7 of this Chapter) in such decks exceeds 15% of the breadth of deck plating used in midship section modulus calculation.

2.4.4.7 The above requirements for deck openings are, in general, also applicable to regions outside 0.5*L* amidships.

### 2.4.5 Lower decks and platform decks with loading not exceeding 40 kPa

2.4.5.1 The thickness *t* of second tier deck plating outside the line of hatchways and within 0.4*L* amidships is not to be less than that obtained from the following formula:

$$t = 12s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

The thickness *t* of second tier deck plating inside the line of hatchways and within 0.075*L* from the ship's ends is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

where: *s* — spacing of frames, in m, to be taken as not less than the standard spacing of frames.

2.4.5.2 The thickness *t* of third tier deck or platform deck plating is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

where: *s* — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

*K* — material factor.

### 2.4.6 Raised quarter decks

2.4.6.1 For the requirements for raised quarterdecks, see 2.17.8 of this Chapter.

### 2.4.7 Superstructure ends

2.4.7.1 The deck strengthening at ends of superstructures is to comply with the requirements of 2.17.6 of this Chapter.

### 2.4.8 Deck coverings

2.4.8.1 The deck coverings are to be of materials which are not corrosive to steel, or they are to be effectively insulated from the steel by a noncorrosive protective coating.

2.4.8.2 Wood sheathing on exposed steel deck is to have a thickness not less than 50 mm for pine and 45 mm for teak wood in ships less than 120 m in length, and 60 mm and 50 mm respectively in ships of 120 m or over in length. For enclosed spaces, the thickness of pine sheathing on the steel deck is not to be less than 40 mm.

The thickness of steel deck plating sheathed with wood planks may be reduced by 1 mm, but each plank is to be well secured to the deck plating at every beam by studs.

2.4.8.3 Where chemical covering is used as a substitute for wood sheathing, the thickness of the steel deck plating is not to be reduced.

# Section 5 SINGLE BOTTOMS

### 2.5.1 Application

2.5.1.1 This Section applies to transversely framed single bottom ships of not greater than 90 m in length.

### 2.5.2 Centre keelson

2.5.2.1 The centre keelsons are to be provided in way of the central longitudinal section of the ship. The depth of the centre keelson is to be the same as that of floors, and the web thickness $t$ and the sectional area $A$ of the face plate of the centre keelson are not to be less than the following:

Within 0.4$L$ amidships: $t = \sqrt{LK} + 2$ mm, and not less than 6 mm

$A = 0.67LK$ cm$^2$, and not less than 12.5 cm$^2$

Within 0.075$L$ from the ship's ends: $t = \sqrt{LK} + 0.5$ mm, and not less than 6 mm

$A = 0.52LK$ cm$^2$, and not not less than 12.5 cm$^2$

where: $L$ — length of ship, in m;

$K$— material factor.

In the forepeak tank, the centreline keelson may have the same depth and thickness and the same sectional area of face plate as the floor.

2.5.2.2 The centre keelson is normally to extend as far forward and aft as practicable. Where the centre keelson is cut in way of a bulkhead, it is to be connected to the bulkhead by one of the following means:

(1) The web plate of the centre keelson is to be gradually raised, within one frame spacing to 1.5 times the original web depth at the bulkhead, and the face plate of the centre keelson is to extend and to be welded to the bulkhead, as shown in Figure 2.5.2.2(1).

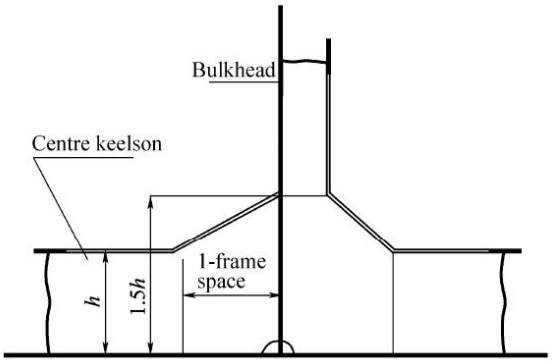



**Figure 2.5.2.2(1)**

(2) The centre keelson is to be attached to the bulkhead by brackets having a face plate or flange, and the depth and length of the brackets are to be equal to the depth of the keelson. In this case, the face plate of the centre keelson may not be welded to the bulkhead. The thickness of the brackets is to be the same as that of the web of the centre keelson, as shown in Figure 2.5.2.2(2).

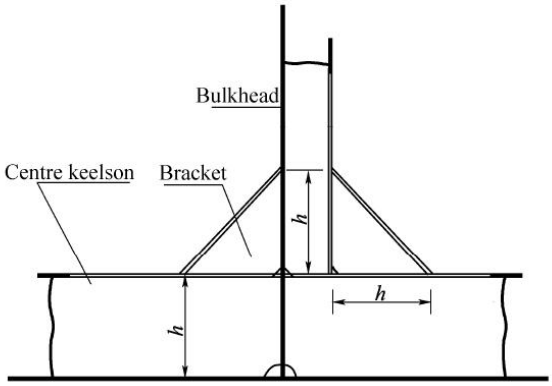



**Figure 2.5.2.2(2)**

(3) The face plate of the centre keelson is, within one frame spacing, to be gradually widened to twice its original width at the bulkhead, and to be welded to the bulkhead, as shown in Figure 2.5.2.2(3).

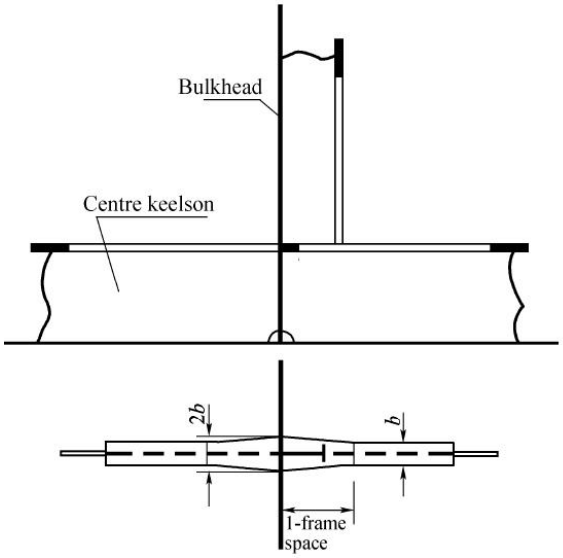



**Figure 2.5.2.2(3)**

2.5.2.3 In the machinery space the thickness of the centre keelson web is to be equal to the value obtained from 2.5.2.1 of this Section plus 1 mm. Where a single main engine is fitted, the centre keelson may be omitted in the machinery space provided that the longitudinal girders under the engine seating extend over the whole length of the engine room and brackets are fitted at the outside of both end bulkheads of the engine room for transition. Within the engine room where the centre keelson is cut, however, gradually tapered brackets having a length not less than two frame spaces are to be fitted for transition, as shown in Figure 2.5.2.3.

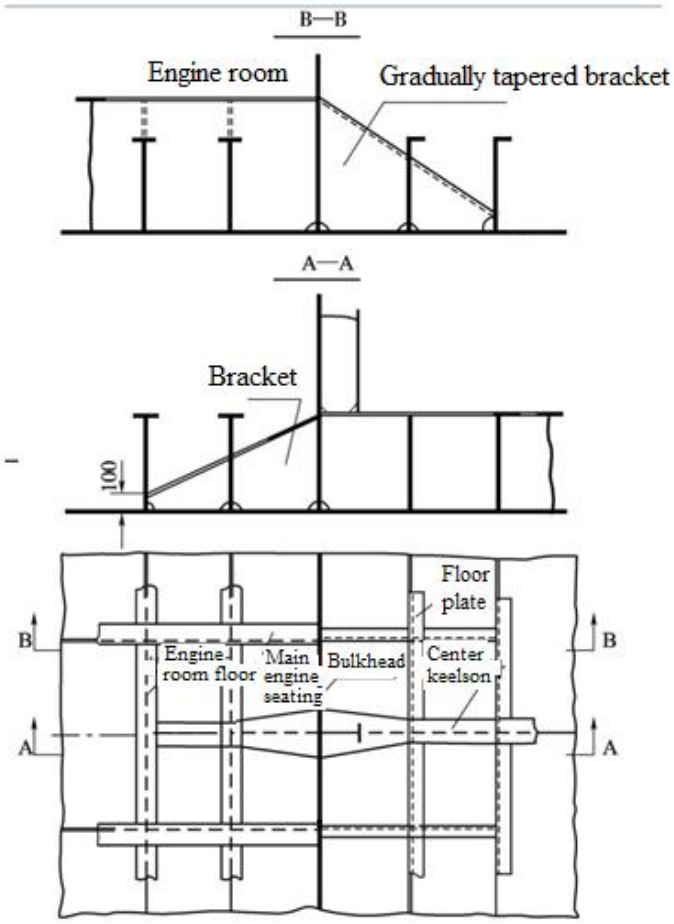



**Figure 2.5.2.3**

In machinery spaces situated at the aft end, such engine seating girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Where it is impracticable to provide transition brackets abaft the aft peak bulkhead because the aft body of the ship is too fine, such brackets may be dispensed with.

### 2.5.3 Side keelsons

2.5.3.1 The depth of side keelsons is to be the same as that of floors, and the web thickness $t$ and the face plate sectional area $A$ of side keelsons are not to be less than the following:

$t = \sqrt{LK}$ mm, and not less than 6 mm

$A = 0.25L+5$ cm$^2$, and not less than 10 cm$^2$

where: $L$ — length of ship, in m;

$K$— material factor.

In the machinery space, the web thickness of side keelsons is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section.

2.5.3.2 One side keelson at least is to be fitted on each side of the centre keelson where the breadth of ship is equal to 9 m or less, and two at least where the breadth exceeds 9 m but does not exceed 16 m. In addition, continuous or intercostal longitudinal stiffeners are to be fitted where the panel aspect ratio exceeds 4. Side keelsons are to be uniformly fitted and are to extend as far

forward and aft as practicable. Outboard of the main engine seating girders, side keelsons as required in 2.5.3.1 of this Section are to be fitted, and attention is to be given to structural continuity. In the case of ships having duplicate main engines situated at the aft end, where it is impracticable to fit the side keelsons owing to the confined space in the engine room, such keelsons may be dispensed with.

2.5.3.3 The attachment of side keelsons to the bulkheads is to be the same as required for the centre keelson (see 2.5.2.2 of this Section).

### 2.5.4 Floors

2.5.4.1 Plate floors are to be fitted at every frame and are, at the centreline, to have a web depth $h$, a web thickness $t$ and a sectional area $A$ of face plate not less than:

$$h = 42(B + d) - 70 \quad \text{mm}$$

$$t = (0.01h+3)\sqrt{K} \text{ mm, but not less than 6 mm and need not be greater than 14 mm}$$

$$A = (4.8d-3)K \quad \text{cm}^2$$

where: $B$ — breadth of ship, in m;

$d$ — moulded draught, in m;

$K$ — material factor.

2.5.4.2 The thickness of the face plate of the floor is not to be less than that of its web plate. The breadth of the face plate is not to be less than 10 times its thickness, but need not exceed 15 times.

2.5.4.3 In ships having considerable rise of floor (or towards fore and aft ends), the depth of floor plates is to be increased. The floor plates forming part of a watertight, deep tank or tank bulkhead are not to be less than 900 mm in depth measured at the centreline, and have a thickness not less than that required for the bottom strake of a bulkhead.

For small ships, the depth of the floor plates at the centreline may be suitably reduced.

2.5.4.4 In machinery spaces the web thickness of floors is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section. In way of machinery spaces situated amidships, the depth of the web plate and the face plate sectional area of floors are to be increased by 10% above those obtained from 2.5.4.1 of this Section. In way of machinery spaces situated astern, the face plate area of floors is to be increased by 10% above those obtained from 2.5.4.1 of this Section. The floors are not to be flanged instead of having face plates.

In way of machinery spaces situated aft or where there is considerable rise of floor, the depth of floors is to be appropriately increased in accordance with the ship's lines and strength.

### 2.5.5 Bilge brackets

2.5.5.1 Floors are to be connected to the frames by bilge brackets. The depth of the bilge brackets measured from the base line is to be twice that of the floors in way of the centreline, and the length of the brackets, measured from the inner edge of frames, is to be equal to the floor depth on the centreline. The thickness of the brackets is to be equal to that of floors. The brackets are to have a flange or face plate. When flanged, the width of the flange is neither to exceed 10 times the thickness of the bracket nor to be less than 50 mm.

2.5.5.2 Where it is impracticable to arrange the bilge brackets due to the ship's lines or other reasons, the floors are to extend to the ship's side and to be raised to the required depth for bilge brackets.

2.5.5.3 Where bilge brackets or floors are connected to the frames by means of a welded lap joint, the length of overlap is to be as follows:
(1) when the depth of frames is 100 mm or less, the length of overlap is not to be less than twice the depth of frames;
(2) when the depth of frames exceeds 100 mm, the length of overlap is neither to be less than 1.5 times the depth of the frame nor less than 200 mm.

### 2.5.6 Drain holes

2.5.6.1 Drain holes are to be cut in the floors and side keelsons in way of the bottom. Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rates required.

## Section 6 DOUBLE BOTTOMS

### 2.6.1 General requirements

2.6.1.1 Double bottoms are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 1 of this PART.
2.6.1.2 Where the double bottom is interrupted, the continuity of bottom longitudinal members is to be maintained. The centre and side keelsons within the single bottom in way of the break are to be the continuation of the centre and side girders of the double bottom. The inner bottom plating is to extend beyond the break of the double bottom and to be gradually tapered for a length of not less than three frame spaces to form the face plate of the keelsons, and the breadth of the face plate at the break of the double bottom is not to be less than half the spacing of side keelsons. The margin plate is also to extend not less than three frame spaces beyond the break of the double bottom. Where the margin plate is inclined, the extension portion is to have a face plate or flange, and the width of the margin plate may be reduced gradually. Within the single bottom, side keelsons, which are not the direct continuation of the girders in the double bottom, are to be extended into the double bottom and to be gradually tapered off over a length of not less than three frame spaces with their free edges flanged.
2.6.1.3 Sufficient girders are to be arranged in way of the main machinery and structural continuity is to be maintained. In midship machinery spaces, these girders are to extend for the full length of the space and are to be carried for at least three frame spaces beyond the fore and after bulkheads of the engine room. However, the extension beyond the after bulkhead is also to support the foremost shaft tunnel bearing; in machinery spaces situated at the aft end such girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses.
Outboard of the main engine seating girders, side girders are to be arranged and attention is to be given to the structural continuity.
2.6.1.4 Manholes are to be cut in the floors and side girders. Except for lightened floors, the depth of manholes is not to exceed 50% of that of the double bottom, unless edge reinforcement is provided. Manholes cut in floors are to be arranged along a straight line in the fore and aft direction for easy access. Manholes or lightening holes are not permitted within the range of floor

ends (generally taken as 1 spacing of longitudinals in way of the longitudinal bulkhead or 600 mm, whichever is greater) and in the side girders for one frame space from transverse bulkheads, unless the edges of holes are strengthened. The edges of all holes are to be smoothed.

2.6.1.5 Air and drain holes are to be cut in floors, side girders and bottom and inner bottom longitudinals to ensure the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

2.6.1.6 The minimum thickness of floors and girders of double bottoms is to be 6 mm.

2.6.1.7 The strake connecting the inner bottom plating to the shell plating is the margin plate.

### 2.6.2 Centre girders

2.6.2.1 Centre girders are to be provided in way of the central longitudinal section of the ship. The depth $h_0$ of centre girders is not to be less than that calculated by the following formula:

$$h_0 = 25B + 42d + 300 \quad \text{mm, nor less than 760 mm}$$

where: $B$ — breadth of ship, in m;

$d$ — draught, in m.

For double hull ships (with double bottom and double side skin), the distance from midpoint between outer and inner shells at one side to that at the other side may be taken as equivalent breadth in lieu of the breadth $B$ of ship (see Figure 2.6.2.1). $B_e$ is generally not to be less than $0.9B$, and if the double bottom strength is in compliance with the CCS criteria for direct strength calculations, not to be less than $0.8B$.

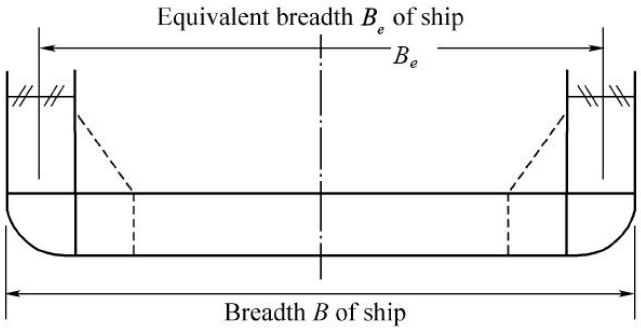



**Figure 2.6.2.1**

2.6.2.2 The thickness $t$ of centre girders is not to be less than:

(1) For $0.4L$ amidships:

$$t = (0.0077h_0+4)\sqrt{K} \quad \text{mm}$$

where: $h_0$ — considered height of double bottom, in mm;

$K$ — material factor.

(2) For $0.075L$ from the ship's ends, the thickness $t$ of centre girders may be decreased by 2 mm from that required in (1) above.

(3) The thickness of centre girders in boiler spaces is to be increased by 2.5 mm above that required for centre girders within $0.4L$ amidships.

2.6.2.3 The centre girders within $0.75L$ amidships are to be continuous and to extend as far as practicable to the stem and stern frame.

2.6.2.4 Manholes or lightening holes are not to be cut in the centre girders within 0.75$L$ amidships, but if such holes are essential in exceptional cases, suitable compensation is to be provided.

Outside 0.75$L$ amidships, holes may be cut in centre girders (excluding one frame space forward and aft of a transverse bulkhead) with a depth not exceeding 40% of that of the centre girders at that place.

### 2.6.3 Duct keels

2.6.3.1 Duct keels (pipe tunnels) may be substituted for centre girders. The thickness of side plates of the duct keel is not to be less than that of the watertight floors. The side plates are in general not to be spaced more than 2 m apart; for ships of 150 m or above in length, the side plates may be spaced not more than 3 m apart upon verification by direct calculation.

The bottom shell and inner bottom within the region of duct keels are to be suitably increased in thickness.

2.6.3.2 The framing members of the duct keel are to be as follows:

(1) Bottom and inner bottom stiffening members are to be fitted to the duct keel at every frame, and the section modulus $W$ of these framing members is not to be less than that obtained from the following formula:

$$W = 22sdl^2K \qquad \text{cm}^3$$

where: $s$ — spacing of frames, in m;

$d$ — draught, in m;

$l$ — span, in m, to be taken as the distance between side plates;

$K$ — material factor.

(2) Bottom and inner bottom stiffening members are to be gradually increased in scantlings at both ends and are to be connected to the side plates of the duct keel. The enlarged portions are to have a length and depth not less than 1.5 times the depth of the members. In such a case, brackets having the same thickness as the plate floors are to be fitted outside the side plates at each frame where no floor is fitted, and are to be attached to the longitudinals.

(3) Bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

2.6.3.3 At the connection between the duct keel and the ordinary centre girder, they are to be overlapped over a length not less than 3 frame spaces for transition.

### 2.6.4 Transverse framing — side girders

2.6.4.1 The thickness of side girders is not to be less than that obtained from the following formula:

$$t = (0.0077h_0+1)\sqrt{K} \qquad \text{mm}$$

where: $h_0$ — considered height of double bottom, in mm.

$K$ — material factor.

The thickness of watertight side girders is to be increased by 1 mm above that obtained from the above formula. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

2.6.4.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 10 m, and at least two side girders spaced apart generally not more than 4 m are

to be fitted on each side of the centreline when the breadth of the ship exceeds 18 m. But forward of 0.2$L$ from the F.P., the spacing of side girders is not to be greater than 3 frame spaces. Side girders are to be equally spaced as far as practicable.

### 2.6.5 Transverse framing — plate floors

2.6.5.1 The thickness $t$ of plate floors in cargo holds or machinery spaces is not to be less than that obtained from the following formula, but need not exceed 15 mm:

$$t = (0.0077h_0+1)\sqrt{K} \quad \text{mm}$$

where: $h_0$ — considered height of double bottom, in mm;

$K$ — material factor.

The thickness of plate floors in boiler rooms and in way of the bilge wells is to be 2.5 mm greater than that given by the above formula.

2.6.5.2 Plate floors are to be fitted at least 4 frame spaces apart at a spacing not exceeding 3.2 m. Where the length of ships exceeds 90 m or the depth of floors exceeds 0.9 m, vertical stiffeners spaced not more than 1.5 m apart are to be fitted on the plate floors, generally having the same thickness as that of floors and the width of which is not to be less than 150 mm. For ships less than 90 m in length, the width of such stiffeners is not to be less than 1.65$L$, with a minimum of 50 mm.

Plate floors are to be fitted at every frame in the engine room and under the boiler bearers, thrust seatings, transverse bulkheads and heels of pillars. Plate floors are to be fitted at every frame forward of 0.2$L$ from the F.P.

### 2.6.6 Transverse framing — watertight floors

2.6.6.1 The thickness of watertight floors is to be as follows:

(1) The thickness of watertight floors is to be 2 mm greater than that of the plate floors in cargo holds, but generally need not exceed 15 mm.

Watertight floors are to be fitted below transverse watertight bulkheads wherever practicable.

(2) The thickness of oiltight floors in oil tanks is to be the same as required for the above watertight floors.

2.6.6.2 Where the depth of watertight floors is greater than 0.9 m but does not exceed 2 m, they are to be fitted with vertical stiffeners spaced not more than 0.9 m apart. Both ends of stiffeners are to be snipped, the thickness and depth are to comply with the requirements of 2.6.5.2, and the section modulus $W$ of which is not to be less than that obtained from the following formula:

$$W = 5.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, from the inner bottom to the top of overflow;

$l$ — span of stiffener, in m, i.e. the considered height of double bottom;

$K$ — material factor.

The section modulus of the stiffeners on the oiltight floors in oil tanks is to be the same as required in the above formula.

2.6.6.3 Where the double bottom tanks are interconnected with side tanks or cofferdams, or the depth of the plate floor is greater than 2 m, the scantlings of the watertight floors are not to be less than those required for deep tanks, furthermore, vertical stiffeners are to be bracketed at both ends.

### 2.6.7 Bracket floors

2.6.7.1 Where transverse framing is adopted in the double bottom, bracket floors are to be fitted at every frame where no plate floor is fitted. The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is not to be less than 75% of the depth of the centre girder, and the thickness of the brackets is to be the same as that of plate floors in that region. Where the depth of the double bottom is equal to 800 mm or more, the brackets are to have a flange or face plate on the unsupported edge and the breadth of the flange or face plate is to be 10 times the thickness but need not exceed 90 mm. Stiffeners having the same scantlings as the reversed frames are to be fitted on one side of the side girders (see Figure 2.6.7.1). Where $l$ as shown in the Figure is greater than 2.5 m, struts as required in 2.6.7.2 of this Section are to be fitted.

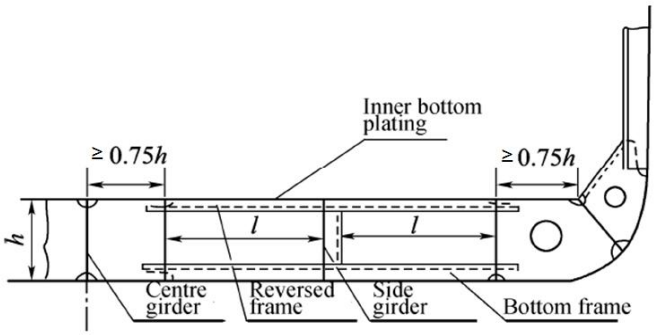



**Figure 2.6.7.1**

2.6.7.2 The bottom frames of bracket floors are to have a section modulus $W$ not less than that obtained from the following formula:

$$W = (15 - 2.5l_1)sdl^2K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;

$d$ — draught, in m;

$l$ — span of bottom frames, in m, measured from the edge of the bracket to the side girder (see Figure 2.6.7.1);

$l_1$ — the same as $l$, but $l_1$ is to be taken as 2.5 m for $l > 2.5$ m;

$K$ — material factor.

Where struts are fitted at the mid-point of the span $l$, the section modulus $W$ of the bottom frames is not to be less than half of that given by the above formula. The cross sectional area $A$ of the struts is not to be less than the following:

$$A = 23.8 + 0.04W \text{ cm}^2 \quad \text{for } W > 85 \text{ cm}^3$$

$$A = 0.32W \text{ cm}^2 \quad \text{for } W \leq 85 \text{ cm}^3$$

where: $W$ — section modulus of bottom frames, in cm³.

The reversed frames are to have a section modulus not less than 85% of that given above for the bottom frames.

In boiler rooms, the thickness of the bottom frames, reversed frames and struts is to be increased by 2 mm.

2.6.7.3 The attachment of bottom frames and reversed frames to brackets is to be the same as required in 2.5.5.3 of this Chapter for the attachment of frames to bilge brackets.

### 2.6.8 Lightened floors

2.6.8.1 Where transverse framing is adopted in the double bottom, lightened floors may be fitted at every frame where no plate floor is fitted, as substitutes for bracket floors. The thickness of the web plate of lightened floors is not to be less than that of the plate floor in the same region. The distance from the edge of the lightening hole to bottom and inner bottom is not to be less than 0.2 times the depth of the centre girder; the distance from the edge of the lightening hole to the centre girder and margin plate is not to be less than 0.5 times the depth of the centre girder; the distance from the edge of the lightening hole to the side girder is not to be less than 0.25 times the depth of the centre girder; and the length of the the lightening hole is not to exceed 1.2 times the depth of the centre girder, as shown in Figure 2.6.8.1.The dimensions of the vertical stiffeners on the floors are to comply with the requirements of 2.6.5.2 of this Section, and the spacing of the stiffeners is not to be more than 2.2 m.

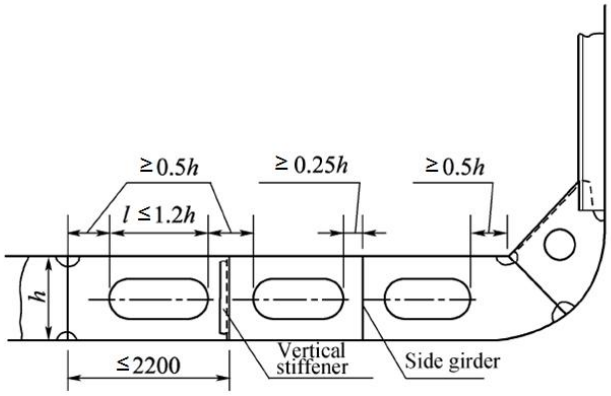



**Figure 2.6.8.1**

### 2.6.9 Transverse framing — inner bottom plating and margin plate

2.6.9.1 The thickness $t$ of the inner bottom plating is not to be less than the following:

$t = (0.04L+5s+2.1)\sqrt{K}$ mm for 0.4$L$ amidships

$t = (0.055L+4.8)\sqrt{K}$ mm for engine spaces

where: $L$ — length of ship, in m, to be taken as not greater than 400 m;

$s$ — spacing of frames, in m;

$K$ — material factor.

For 0.075$L$ from the ship's ends, the thickness is to be 0.9 times that required for 0.4$L$ amidships. The thickness of the inner bottom plating in other regions is to be tapered gradually to the end thickness from the thickness within 0.4$L$ amidships.

2.6.9.2 Local strengthening of inner bottom plating:

(1) Where the double bottom tanks are used to carry oil fuel, the thickness of the inner bottom plating is not to be less than 8 mm.

(2) The thickness of the inner bottom plating under hatchways is to be increased at least by 2 mm if no wood ceiling is fitted. If cargo is regularly discharged by grabs or other similar means and where no wood ceiling as required in 3.3.1.5 of this PART is fitted, the thickness of the inner bottom plating under hatchways is to be increased at least by 5 mm.

2.6.9.3 Where the margin plate is inclined downwards, the breadth of the margin plate is not to be less than 80% of the depth of the centre girder. Where the margin plate is horizontal, the breadth is not to be less than that of bilge brackets plus 50 mm.

Where the margin plate is inclined downwards, the thickness of the margin plate throughout the hold is to be 1.5 mm greater than that required for the inner bottom plating when the length of the ship is equal to 110 m or less, and 2 mm when the length of the ship is greater than 110 m. In engine rooms and boiler rooms, the thickness of the margin plate is not to be less than that required for the inner bottom plating within such spaces respectively.

### 2.6.10 Longitudinal framing — bottom girders

2.6.10.1 The depth and thickness of the centre girder are to be the same as required in 2.6.2.1 and 2.6.2.2 of this Section. Between plate floors, brackets having the same thickness as the plate floors are to be fitted on each side of the centre girder, extending to the adjacent longitudinals. Such brackets are in general to be spaced not more than 1.20 m apart. Where the centre girder is watertight, vertical stiffeners spaced not more than 0.9 m apart are to be fitted between the plate floors and brackets (when the distance between them is greater than one frame space). For these stiffeners, the section modulus is to comply with the requirements of 2.6.6.2, the thickness is to be the same as that of the center girder web and in general, the breadth is to comply with the requirements of 2.6.5.2.

2.6.10.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 12 m but not greater than 20 m, and at least two side girders spaced apart generally not more than 5 m are to be fitted on each side of the centreline when the breadth of the ships exceeds 20 m. Forward of 0.2$L$ from the F.P. the spacing of side girders is not to be greater than four longitudinal spaces. The side girders are to be equally spaced as far as practicable.

The thickness of side girders and watertight side girders are to comply with the requirements of 2.6.4.1 of this Section. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

Side girders and watertight side girders are in general to be fitted with vertical stiffeners. Vertical stiffeners of side girders are to be spaced not more than 1.5 m apart, having the same thickness as that of side girder webs and generally, a breadth is to comply with the requirements of 2.6.5.2. Vertical stiffeners of watertight side girders are to be spaced not more than 0.9 m apart, the thickness is to be the same as that of watertight side girder web and generally, the breadth is to comply with the requirements of 2.6.5.2 and the section modulus $W$ is to comply with the requirements of 2.6.6.2.

Where side girders and watertight side girders are fitted with horizontal stiffeners, the thickness of stiffeners is generally the same as that of side girder webs and the breadth is to comply with the requirements of 2.6.5.2. The section modulus $W$ of horizontal stiffeners on watertight side girders is to comply with the requirements of 2.6.6.2.

### 2.6.11 Longitudinal framing — plate floors

2.6.11.1 In machinery spaces, plate floors are to be fitted at least at alternate frames, and are to be fitted at every frame under the main engine seating, boiler bearers, thrust seatings, transverse bulkheads and heels of pillars.

Plate floors are to be fitted at alternate frames within the region forward of 0.2$L$ from the F.P. Elsewhere, the spacing of the plate floors is not to exceed 3.6 m.

2.6.11.2 The thickness of plate floors for longitudinally framing is to be 10% greater than that required in 2.6.5.1 of this Section, but need not exceed 15 mm, and the thickness of watertight and oiltight floors is to be the same as required in 2.6.6.1 of this Section.

Vertical stiffeners are to be fitted at each longitudinal. The thickness of vertical stiffeners for floors is to be the same as that of the floors and the width of which is to comply with the requirements of 2.6.5.2. In addition, the scantlings of vertical stiffeners for watertight floors are to comply with the requirements of 2.6.6.2 of this Section. Vertical stiffeners are to be attached to the inner bottom and shell longitudinals by welding.

The ratio of thickness to depth of the floors is not to be less than 1/130. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of watertight floors and the stiffeners are to be as required for deep tanks.

### 2.6.12 Longitudinal framing — bottom longitudinals

2.6.12.1 The spacing of bottom longitudinals is not to be greater than 1 m.

2.6.12.2 The section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = \frac{8.5f}{1.73 - F_b}(d + h_1)sl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$l$ — span of longitudinal, in m, but not less than 1.5 m;

$d$ — draught, in m;

$f$ — factor, taken as 0.52 when intermediate vertical struts are fitted, or 1.0 when no intermediate vertical strut is fitted;

$F_b$ — reduction factor, see 2.2.5.6 of this Chapter;

$h_1$ — see 2.3.1.2 of this Chapter;

$K$ — material factor.

Where the spacing of plate floors is greater than 2.5 m, vertical struts connecting the bottom longitudinals and inner bottom longitudinals may be fitted at the midpoint of the spacing, and the cross sectional area $A$ of the vertical struts is not to be less than the following:

$A = 23.8 + 0.04W$ cm² for $W > 85$ cm³

$A = 0.32W$ cm² for $W \leq 85$ cm³

where: $W$ — section modulus of longitudinals, in cm³.

2.6.12.3 The section modulus of inner bottom longitudinals is to be equal to 85% of that of the bottom longitudinals. In boiler rooms, the thickness of the longitudinals, struts and brackets is to be increased by 2 mm.

2.6.12.4 Where longitudinals pass through non-watertight floors, they are to be welded to the floors and the vertical stiffeners on the floors in way. Where longitudinals are cut in way of watertight floors, they are to be bracketed to the watertight floors. The scantlings of the brackets are to comply with the requirements of 1.2.6 of this PART. Where the length of the ship exceeds 200 m or higher tensile steel is used, the bottom longitudinals are to be continuous in way of watertight floors, or alternative arrangements may be considered.

### 2.6.13 Longitudinal framing — inner bottom plating and margin plate

2.6.13.1 The thickness of the inner bottom plating is to comply with the requirements of 2.6.9 of this Section. But for the calculation of the thickness of the inner bottom plating within 0.4*L* amidships, the *s* in the formula is to be taken as the spacing of longitudinals, and the value considered may be reduced by 1 mm.

2.6.13.2 The thickness of the margin plate is to comply with the requirements in 2.6.13.1 of this Section and in addition, is to be increased in accordance with the requirements of 2.6.9.3 of this Section.

2.6.13.3 The margin plate is to be provided with brackets at every frame, extending to the adjacent longitudinal, as shown in Figure 2.6.13.3. The edges of the brackets are to be strengthened, and the thickness of the brackets is to be the same as that of floors.

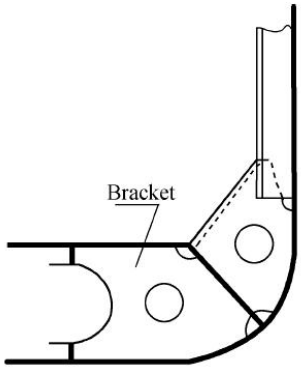



**Figure 2.6.13.3**

### 2.6.14 Reinforcement for using fork lift trucks in cargo holds

2.6.14.1 Where fork lift trucks are used for handling cargo in holds, the inner bottom plating and framing are to comply with the relevant requirements of Section 21 of this Chapter for vehicle decks.

### 2.6.15 Tank side brackets

2.6.15.1 Tank side brackets are to be fitted at every frame and their thickness is to be the same as that of plate floors. Circular lightening holes may be cut in the tank side brackets and the distance from any point of hole edges to the side of brackets is not to be less than 1/3 breadth of the bracket.

2.6.15.2 Tank side brackets are to be flanged or provided with a face plate on the free edge, and the breadth of the flange or face plate is generally to be 10 times the thickness of the bracket.

2.6.15.3 The standard depth and breadth of tank side brackets are to be as follows:

The depth of tank side brackets connecting secondary members is to be equal to 10% of the distance between the inner bottom and nearest deck or 2.2 times the depth of the web of frames, whichever is the greater. The depth of tank side brackets connecting primary members is to be equal to 1.65 times the depth of the web of frames. The breadth of tank side brackets is to be equal to their depth. The breadth and depth of tank side brackets are to be measured in accordance with Figure 2.6.15.3. Where the inner bottom margin plate of the double bottom is horizontal, vertical stiffeners are to be fitted to the floors under the toes of the brackets (as shown in Figure 2.6.15.3). The requirements for the stiffeners are to be the same as required in 2.6.5.2 of this Section.

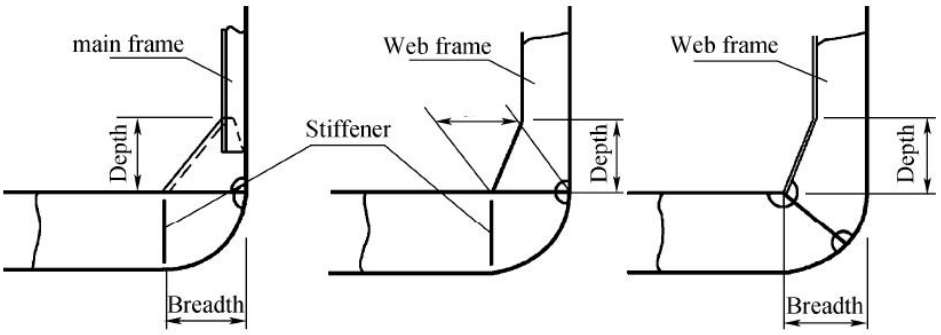



**Figure 2.6.15.3**

2.6.15.4 Where lap joint is adopted for the connection of tank side brackets to frames, the length of overlap is to comply with the requirements of 2.5.5.3 of this Chapter.

2.6.15.5 Where bottom and sides of the ship are framed longitudinally and no bilge longitudinals are fitted, the transverse strength members or corresponding bilge brackets in way are to have a spacing $S$ not exceeding:

$$S = 8 \times 10^6 \frac{t^2}{Dr}\sqrt{\frac{t}{r}} \quad \text{mm}$$

where: $t$ — thickness of bilge plating, in mm;

$D$ — moulded depth, in m;

$r$ — radius of the bilge, in mm.

Furthermore, a suitable number of intermediate bilge brackets connected to the longitudinals situated at the upper and lower turns of the bilge are to be fitted between the plate floors.

# Section 7 SIDE FRAMING

### 2.7.1 General requirements

2.7.1.1 The maximum spacing of frames or side longitudinals is not to be greater than 1.0 m.

### 2.7.2 Frames

2.7.2.1 The section modulus $W$ of main frames (except those in fore and after peaks) is not to be less than that obtained from the following formula:

$$W = cc_1 sdl^2 K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;

$d$ — draught, in m;

$l$ — span of frames, but in no case is it to be taken as less than $\sqrt{D}$ ($D$ being moulded depth), in m. For frames between collision bulkhead and $0.2L$ from F.P., it is to be the greatest frame span of the similar structural arrangement in that region:

$$c = \frac{2 + \frac{0.65d}{D}}{1.45 - \frac{\sqrt{D}}{l}}$$

$c_1$ — coefficient: $c_1 = 1.05$ for $L < 90$ m; $c_1 = 1$ for $L \geq 90$ m;

$K$ — material factor.

2.7.2.2 Corrections to the section modulus of main frames:

(1) Where the depth of tank side brackets is less than that required in 2.5.5.1 or 2.6.15.3 of this Chapter, the section modulus of main frames is to be increased by 2.7% of the value required in 2.7.2.1 of this Section for each reduced 100 mm.

(2) Where the arm length of the brackets connecting main frames to beams or deck longitudinals at side is greater than that required in 1.2.6.7 of this PART, the section modulus of main frames may be decreased by 1.3% of the value required in 2.7.2.1 of this Section for each increased 100 mm of difference.

2.7.2.3 Where side stringers are uniformly fitted in compliance with the requirements of 2.7.3.1 of this Section, the section modulus of main frames may be reduced in accordance with the following:

(1) Where one stringer is fitted, the section modulus of main frames may be 1/2 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

(2) Where two stringers are fitted, the section modulus of main frames may be 2/7 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

(3) Where three stringers are fitted, the section modulus of main frames may be 1/5 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

2.7.2.4 The section modulus of the main frames under hatch end beams is not to be less than 1.67 times that of normal main frames as required in this Section.

2.7.2.5 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of mains frames in the machinery spaces is to be 50% greater than that normally required.

2.7.2.6 The scantlings of main frames are in no case to be less than those of 'tween decks above, and the main frame section modulus is not to be less than 20 $cm^3$.

2.7.2.7 The moment of inertial $I$ of main frames is not to be less than that obtained from the following formula:

$$I = 3.2Wl/K \quad cm^4$$

where: $W$ — section modulus of main frames as required in this Section, in $cm^3$;

$l$ — span of frames, in m, as required in 2.7.2.1 of this Section where fitted with no side stringer, or being the vertical distance measured from the upper edge of floor or top of inner bottom to the side stringer or between side stringers or from the side stringer to the lowest deck at side where fitted with side stringers;

$K$ — material factor.

2.7.2.8 The frames in fore and after peaks are to comply with the following requirements:

(1) The section modulus $W$ and the moment of inertia $I$ of primary frames below the lowest deck in fore and after peaks are to be respectively not less than the values obtained from the following formulae:

$$W = 4.6sdDK \quad cm^3$$

$$I = 3.5Wl/K \qquad \text{cm}^4$$

where: $s$ — spacing of frames, in m;

$d$ — draught, in m;

$D$ — moulded depth, in m;

$L$ — span of frames, in m, being the vertical distance measured from the upper edge of floor to the side stringer (perforated flat), or distance between side stringers (perforated flats) or from the side stringer (perforated flat) to the lowest deck;

$K$— material factor.

(2) Where the lowest deck in the fore peak is below 1.0 m above the full-load waterline, the 'tween deck frames fitted from the lowest deck up to 1.0 m above the full-load waterline are also to comply with the requirements of (1) above.

(3) Other 'tween deck frames in the fore peak are also to comply with the requirements of 2.7.2.9 of this Section.

2.7.2.9 The section modulus $W$ of the frames in 'tween decks and superstructures is not to be less than that obtained from the following formula:

$$W = CC_1sdl\sqrt{D}\,K \quad \text{cm}^3$$

where:

$s$ — spacing of frames, in m;

$d$ — draught, in m;

$l$ — span of frame, in m. For frames in 'tween deck space where the actual span is less than 2.6 m, $l$ = 2.6 m is to be taken and for those in superstructures where the actual span is less than 2.3 m, $l$ = 2.3 m is to be taken;

$D$ — moulded depth, in m;

$C$ — coefficient, to be taken as $C = 0.7 + 4\frac{d}{D}$;

$C_1$ — coefficient, to be determined by the position of frame: $C_1$ = 1.0 for those in the first 'tween deck below the upper deck; $C_1$ = 1.1 for those in the second 'tween deck; $C_1$ = 1.45 for those in the third and lower 'tween decks; $C_1$ = 0.90 for those in forecastle; $C_1$ = 0.80 for those in bridge and poop;

$K$ — material factor.

2.7.2.10 The section modulus of the frames under hatch end beams in 'tween deck spaces is not to be less than 1.67 times that of normal 'tween deck frames, as required in this Section.

2.7.2.11 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of the 'tween deck frames under the lowest deck above the load waterline is to be 50% greater than that normally required.

2.7.2.12 Where the length of the forecastle or poop exceeds 0.25$L$, the scantlings of the two frames fitted at the after end of the forecastle or at the fore end of the poop are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the forecastle or poop.

2.7.2.13 The scantlings of four frames fitted at each end of the bridge are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the bridge.

2.7.2.14 The end connections of frames are to comply with the following:

(1) The scantlings of brackets connecting beams to upper ends of frames are to comply with 1.2.6 of this PART. Where decks are framed longitudinally, the brackets at the upper end of frames are to be extended to the nearest deck longitudinal and welded to it.
(2) The tank side brackets at the lower ends of main frames are to comply with the relevant requirements in Sections 5 and 6 of this Chapter.
(3) Where 'tween deck frames terminate at lower decks, their lower ends are to be bracketed. The scantlings of the brackets are to be the same as those at the upper end of 'tween deck frames. Where the 'tween deck frames and the frames thereunder are directly attached to the lower deck by welding, the lower end of the 'tween deck frames may not be bracketed.

### 2.7.3 Side stringers

2.7.3.1 Where side stringers are fitted to support the main frames and 'tween deck frames, the section modulus $W$ and the moment of inertia $I$ of the side stringers are not to be less than those obtained from the following formulae respectively:

$$W = 7.8hbl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $b$ — width of areas supported by the side stringers, in m;
$h$ — vertical distance, in m, measured from the mid-span of side stringer to upper deck at side;
$l$ — span of side stringers, in m;
$K$ — material factor.

2.7.3.2 Brackets are to be fitted at the connection between side stringers and transverse bulkheads, and the requirements of 1.2.7 of this PART are to be complied with. Side stringers and web frames are to be so connected that an adequate continuity of the face plate or flange of side stringers is kept.

2.7.3.3 In transversely framed machinery spaces, side stringers are to be fitted to support main frames where the main frame span exceeds 6 m and their section modulus and moment of inertia are to comply with 2.7.3.1 of this Section and their web depth is not to be less than 2.5 times that of main frames.

2.7.3.4 In transversely framed machinery spaces, an arrangement of intercostal side stringers spaced generally 2.5 m apart may be accepted as an alternative to the side stringers specified in 2.7.3.3 of this Section and their web depth is to be the same as that of main frames, their web thickness $t$ and sectional area $A$ are to be respectively not less than those obtained from the following formulae:

$$t = 0.023L + 6 \quad \text{mm}$$
$$A = (0.14L + 1)K \quad \text{cm}^2$$

where: $L$ — length of ship, in m, to be taken as not greater than 215 m in calculation;
$K$ — material factor.

### 2.7.4 Transverse framing − web frames

2.7.4.1 The scantlings of web frames supporting side stringers are to be determined by direct calculation based on the assumptions that their both ends are rigidly fixed and that they are subject to concentrated loadings transmitted by side stringers (the considered pressure head being the distance from the mid-span of side stringers to upper deck at side, in m), with the permissible

bending stress being taken as 93.2/$K$, in N/mm² and the allowable shear stress as 83.4/$K$, in N/mm².

2.7.4.2 Where machinery spaces are situated aft and the ship's sides are transversely framed, web frames are to be fitted and spaced not more than five frame spaces apart in the machinery spaces, extending from the inner bottom to the upper deck.

2.7.4.3 In the areas of transversely framed machinery spaces, the scantlings of web frames supporting side stringers are to be determined in accordance with 2.7.4.1 of this Section.

2.7.4.4 In the areas of transversely framed machinery spaces, the section modulus $W$ of web frames not supporting side stringers is not to be less than that obtained from the following formulas:

$W = 5Shl^2K$ cm³ for spaces below the lowest deck

$W = 3.5Sdl\sqrt{D}\,K$ cm³ for 'tween decks

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of web frame to upper deck at side;

$l$ — span of web frame, in m;

$d$ — draught, in m;

$D$ — moulded depth, in m;

$K$ — material factor.

2.7.4.5 In the areas of transversely framed machinery spaces, the web depth of web frames is not to be less than 2.5 times the depth of adjacent frames.

2.7.4.6 The end connections of web frames for transverse framing are to comply with the relevant provisions in 2.6.15 and 2.8.7.9 of this Chapter.

### 2.7.5 Side longitudinals

2.7.5.1 The section modulus $W$ of side longitudinals below the upper deck (including bilge longitudinals) is not to be less than that obtained from the following formula:

$$W = \frac{8.5}{f} hsl^2 K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$l$ — span of longitudinals, in m;

$f$ — factor, to be taken in accordance with following two formulae, and to be taken as not greater than 1.077:

$$f = 1.73 - F_d \frac{Z - Z_n}{D - Z_n} \quad \text{for } Z \geq Z_n$$

$$f = 1.73 - F_b \frac{Z_n - Z}{Z_n} \quad \text{for } Z < Z_n$$

$h$ — design pressure head, to be taken from the following formula:

$$h = 0.26C + d - \frac{Z}{D}(0.06C + d)$$

$Z_n$ — the height of horizontal neutral axis, from base line, of hull cross section, in m;

$D$ — moulded depth, in m;

$d$ — draft, in m;

$C$ — coefficient, see 2.2.3.1 in Section 2 of this Chapter;

$F_b$, $F_d$ — reduction factors, see 2.2.5.6 in Section 2 of this Chapter;

$Z$ — height of longitudinals from base line, in m;

$K$ — material factor.

2.7.5.2 Within the region between $0.2L$ from the F.P. and the forepeak bulkhead, the section modulus of side longitudinals below the upper deck is to be in accordance with 2.7.5.1 of this Section and also in accordance with 2.7.5.4 of this Section.

2.7.5.3 For machinery spaces situated aft, the section modulus of side longitudinals in the areas of the machinery spaces is to be in accordance with 2.7.5.1 of this Section and in addition, not less than 0.8 times that obtained from the formula in 2.7.5.5.

2.7.5.4 In the forepeak, the section modulus $W$ of side longitudinals is to be taken as not less than that obtained from the following formula:

$$W = 7.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$h$ —vertical distance, in m, measured from the longitudinal to 3 m above the minimum bow height required by the load line, not less than the vertical distance from the longitudinal to upper deck at side;

$l$ — span of longitudinals, in m, but taken as not less than 1.5 m;

$K$ — material factor.

2.7.5.5 In the aft peak, the section modulus $W$ of side longitudinals is to be taken as not less than that obtained from the following formula:

$$W = 8.5sl^2(h + 0.167D)K \quad \text{cm}^3$$

where:

$s$ — spacing of longitudinals, in m;

$l$ — span of longitudinals, in m, but taken as not less than 1.5 m;

$h$ — vertical distance from the longitudinal to upper deck at side, in m, but not to be less than 3 m;

$D$ — moulded depth, in m, but taken as not greater than 20 m;

$K$ — material factor.

2.7.5.6 The section modulus of side longitudinals (including bilge longitudinals) need not be greater than that of bottom longitudinals with the same spacing.

2.7.5.7 The side longitudinals are to penetrate web frames and the intersections of longitudinal webs and frame webs are to be welded. Where a side longitudinal is cut in way of a transverse bulkhead, brackets are to be fitted at the connection between the longitudinal and the bulkhead, and the brackets are to comply with the relevant provisions in 1.2.6 of this PART.

### 2.7.6 Longitudinal framing — web frames

2.7.6.1 Where the side is framed longitudinally, web frames supporting side stringers are to be fitted in line with plate floors. In general, the spacing of web frames is not to be greater than 3.6 m for ships of 100 m in length or less, and not greater than $0.006L + 3.0$ m ($L$ being length of ship) for ships more than 100 m in length. In the forepeak and aft peak, the spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less, and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.7.6.2 Other than in machinery spaces and forepeak and aft peak, the section modulus $W$ of web frames is not to be less than that obtained from the following formula:

$$W = 10ShlK \quad \text{cm}^3$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

$l$ — span of web frame, in m;

$K$ — material factor.

2.7.6.3 In longitudinally framed machinery spaces, the section modulus $W$ of web frames is not to be less than that obtained from the following formula:

$$W = 10ShlK \quad \text{cm}^3 \quad \text{below the lowest deck}$$

$$W = 4.4Sdl\sqrt{D}\,K \quad \text{cm}^3 \quad \text{in 'tween decks}$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

$l$ — span of web frame, in m;

$d$ — draught, in m;

$D$ — moulded depth, in m;

$K$ — material factor.

The web depth of web frames is not to be less than 2.5 times that of the side longitudinal supported by it.

2.7.6.4 In the longitudinally framed forepeak, the section modulus $W$ and the moment of inertia $I$ of web frames are respectively not to be less than those obtained from the following formulae:

$$W = 14ShlK \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of the web frame to tank top or half of the vertical distance from the mid-span of the web frame to the top of overflow, whichever is the greater;

$l$ — span of web frame, in m;

$K$ — material factor.

Where struts are fitted, the web frames and struts are to comply with the relevant provisions of Section 5 of Chapter 6 of this PART.

2.7.6.5 In the longitudinally framed aft peak, the section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 10ShlK \quad \text{cm}^3$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

$l$ — span of web frame, in m;

$K$ — material factor.

2.7.6.6 The end connections of web frames for longitudinal framing are to comply with the relevant provisions in Sections 6 and 8 of this Chapter and Chapter 5 of this PART.

# Section 8 DECK FRAMING

### 2.8.1 General requirements

2.8.1.1 The design head $h$ of decks is to be determined according to Table 2.8.1.1, and the corresponding design load $p$ is to be calculated by the following formula:

$$p = \frac{9.81h}{\gamma} \quad \text{kPa}$$

where: $h$ — design head, in m, see Table 2.8.1.1 of this Section;

$\gamma$ — stowage rate, in $m^3/t$, taken as the standard rate of 1.39 $m^3/t$.

For decks in deep tanks, the relevant requirements in Section 13 of this Chapter are also to be complied with, and the corresponding design load $P$ is to be calculated by the following formula:

$$p = 9.81\rho h \quad \text{kPa}$$

where: $h$ — design head, in m, see Section 13 of this Chapter;

$\rho$ — density of liquid, in $t/m^3$, to be taken not less than 1.025 $t/m^3$.

**Design Heads of Decks Table 2.8.1.1**

| Name and location of deck | Design head $h$ (m) | Permissible cargo load (kPa) |
|---|---|---|
| Weather decks (minimum sizes of structural members): | | |
| Forward of 0.075$L$ from F.P. | Primary members: $h_0 + 3$; Secondary members: 1.5 $h_0$ | 8.5 |
| Between 0.075$L$ and 0.15$L$ from F.P. | Primary members: $h_0 + 2$; Secondary members: 1.25 $h_0$ | 8.5 |
| Aft of 0.15$L$ from F.P. | $h_0$ | 8.5 |
| Weather decks (specified cargo load): | | |
| Forward of 0.075$L$ from F.P. | $0.49p + h_0 - 1.2$ | $p$ (> 8.5) |
| Between 0.075$L$ and 0.15$L$ from F.P. | $0.37p + h_0 - 1.2$ | $p$ (> 8.5) |
| Aft of 0.15$L$ from F.P. | $0.14p + h_0 - 1.2$ | $p$ (> 8.5) |
| Cargo decks not exposed to weather | 0.14$p$, but not to be less than mean height $H$, in m, of 'tween decks | Max ($p$, 7.06$H$) |
| Accommodation decks | 1.2 | — |
| Decks for stores | 2.0 | — |
| Decks for E.R. platform, workshop and stores | 2.6 | — |
| Superstructure decks: | | |
| 1st tier | 0.90, increased for exposed portion $h_0 - 1.2$ | — |
| 2nd tier | 0.60, increased for exposed portion $h_0 - 1.2$ | — |
| 3rd tier and above | 0.45, increased for exposed portion $h_0 - 1.2$ | — |
| Forecastle deck forward of 0.2$L$ from F.P. | Same as weather decks in corresponding locations | — |

Notes: ① $h_0$ in the Table is not to be less than that obtained from the following formula, but it is neither to be less than 1.2 m, nor greater than 1.5 m:

$$h_0 = 1.20 + \frac{2}{1000}\left(\frac{100 + 3L}{D - d} - 150\right) \quad \text{m}$$

where: $L$ — length of ship, in m;
$D$ — moulded depth, in m;
$d$ — draught, in m.

② For ships less than 90 m in length, the design head of primary members within the areas of fore and aft ends of ships may be appropriately reduced, but not less than that of secondary members at the same location.

③ The superstructure deck is defined in 2.17.1.6 of this Chapter.

### 2.8.2 Deck beams

2.8.2.1 The section modulus $W$ of deck beams is not to be less than that obtained from the following formula:

$$W = (C_1C_2Dd + C_3shl^2)K \quad \text{cm}^3$$

where: $C_1$ — coefficient, dependent on the number of decks (including bridge, poop decks and engine room platform) at the position of the beam under consideration: $C_1$ = 2.0 for 1st tier, $C_1$ = 1.33 for 2nd tier, $C_1$ = 1.05 for 3rd tier, $C_1$ = 0.93 for 4th tier and above, $C_1$ = 1.33 for forecastle deck;

$C_2$, $C_3$ — coefficients, see Table 2.8.2.1;

$D$ — moulded depth, in m;

$d$ — draught, in m;

$s$ — spacing of beams, in m;

$h$ — design head, in m, see 2.8.1.1 of this Section;

$l$ — span of beam, in m, to be taken not less than 2 m;

$K$ — material factor.

**Coefficients $C_2$ and $C_3$** **Table 2.8.2.1**

| Location of deck | $C_2$ | $C_3$ |
|---|---|---|
| Weather/strength deck or exposed forecastle deck forward of 0.075$L$ from F.P. | 0.8 | 0.54$B$ |
| Weather/strength deck or exposed forecastle deck between 0.075$L$ and 0.15$L$ from F.P. | 0.8 | Beams connected to ship side: 0.36$B$ |
| Weather/strength deck or exposed forecastle deck aft of 0.15$L$ from F.P. | 0.54 | Beams elsewhere: 0.33$B$ |
| Short bridge and poop deck where exposed to the weather | 0.14 | |
| Cargo decks and other decks (engine room, forepeak tank and aftpeak tank platforms) | 0.40 | 4.0 |
| Accommodation strength decks or lower decks | 0.52 | 4.0 |

Note: $B$ in the Table is the breadth of ship, in m.

2.8.2.2 The section modulus $W$ of weather deck beams need not be greater than that obtained from the following formula:

$$W = Bshl^2K \quad \text{cm}^3$$

where: $B$ — breadth of ship, in m, to be taken as not greater than 21.5 m;

$s$, $h$, $l$ — see 2.8.2.1 of this Section;

$K$ — material factor.

2.8.2.3 The web depth of deck beams is not to be less than 60 mm.

2.8.2.4 The connections between beams and frames are to comply with the requirements in 1.2.6 of this PART.

2.8.2.5 Beams are to pass through deck girders, and they are to be connected to the girder web by welding. Where beams are to be cut in way of the web of hatch side girders or deck girders, the beams are to be bracketed to the girders and the scantlings of brackets are to comply with the provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of deck girders.

### 2.8.3 Transverse framing — deck girders

2.8.3.1 For weather strength deck forward of 0.075*L* from F.P., the spacing of deck girders supporting beams is not to be greater than 3.6 m. For the upper and lower decks after the aft peak bulkhead, the spacing of deck girders supporting beams is not to be greater than 3 m.

2.8.3.2 The section modulus *W* of deck girders supporting beams is not to be less than that obtained from the following formula:

$$W = 4.75bhl^2K \quad \text{cm}^3$$

where: *b* — mean width, in m, of deck area supported by deck girders;

*h* — design head of deck, in m, see 2.8.1.1 of this Section;

*l* — span of deck girder, in m;

*K* — material factor.

2.8.3.3 Where deck girders arranged to support beams are subject to a concentrated load, their section modulus *W* is to be not less than that obtained from the following formula:

$$W = 0.102cPlK \quad \text{cm}^3$$

where: *P* — concentrated load, in kN;

*l* — span of deck girder, in m;

*c* — coefficient, to be obtained from Table 2.8.3.3 where *a* is the distance, in m, between the application point of concentrated load *P* and the farther one of two supports of the girder;

*K* — material factor.

**Coefficient *C*** **Table 2.8.3.3**

| *a/l* | 0.94 | 0.90 | 0.85 | 0.80 | 0.75 | 0.70 | 0.60 | 0.50 |
|---|---|---|---|---|---|---|---|---|
| *c* | 1.44 | 3.36 | 5.68 | 7.36 | 8.64 | 9.20 | 9.60 | 10 |

2.8.3.4 Where deck girders arranged to support beams are subject to two or three point loads, their section modulus *W* is to be determined by direct calculations assuming fixed ends and using an allowable bending stress of 124/*K*, in N/mm².

2.8.3.5 The section moment of inertia *I* of deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: *W* — section modulus of deck girders required in this Section, in cm³;

*l* — span of deck girder, in m;

*K* — material factor.

2.8.3.6 The web depth of deck girders is not to be less than 1.6 times the depth of cut-outs for the passage of beams. The cut-outs in deck girders are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck girders is not to be less than 1% of the web depth plus 4 mm.

2.8.3.7 Holes cut for the passage of pipes or cables in the web of deck girders are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of beams or

the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of girders. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the adjacent frame spaces. No holes are to be cut on the girder web within 200 mm from the toe of girder brackets.

2.8.3.8 The ends of deck girders are to be connected to transverse bulkheads in accordance with the relevant provisions in 1.2.7 of this PART. For deck girders contributing to the longitudinal strength, special attention is to be paid to the longitudinal structural continuity at transverse bulkheads.

### 2.8.4 Transverse framing — deck transverses

2.8.4.1 For deck transverses supporting deck girders, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck girders and using an allowable bending stress of $124/K$, in N/mm².

2.8.4.2 The section moment of inertia $I$ of deck transverses supporting deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: $W$ — section modulus of deck transverses, in cm³, obtained according to 2.8.4.1 of this Section;

$l$ — span of deck transverse, in m;

$K$ — material factor.

2.8.4.3 The thickness and cutouts of the web of deck transverses supporting deck girders are to comply with the provisions in 2.8.7.7 and 2.8.7.8 of this Section.

2.8.4.4 The connections between deck transverses supporting deck girders and frames or web frames or longitudinal bulkheads are to comply with the provisions of 2.8.7.9 of this Section.

### 2.8.5 Deck longitudinals

2.8.5.1 The section modulus $W$ of weather/strength deck longitudinals is not to be less than the greater obtained from the following formulae:

$$W = c_1 shl^2 K \quad \text{cm}^3$$

$$W = (c_2 sh + c_3 sl^2 L^2 \times 10^{-4})K \quad \text{cm}^3$$

where:

$s$ — spacing of longitudinals, in m;

$h$ — design head of deck, in m, to be determined according to 2.8.1.1 of this Section, but outside the line of deck openings within $0.4L$ amidships:

$$h \geq \frac{22.6L}{1780 - L};$$

$l$ — span of longitudinal, in m, to be taken as not less than 2 m;

$c_1$, $c_2$, $c_3$ — coefficients, to be determined according to Table 2.8.5.1;

$L$ — length of ship, in m, $L$ need not be taken as greater than 200 m;

$K$ — material factor.

**Coefficients $c_1$, $c_2$, $c_3$** **Table 2.8.5.1**

| Item | Location of deck longitudianl | Region | $c_1$ | $c_2$ | $c_3$ |
|---|---|---|---|---|---|
| 1 | Forward of 0.075$L$ from F.P. | | 12.5 | 63.5 | 7.8 |
| 2 | Between 0.075$L$ ~ 0.15$L$ from F.P. | | 12.5 | 57 | 7.2 |
| 3 | At 0.15$L$ from F.P. | Outside the line of openings | 9 | 48.5 | 6.2 |
| | | Inside the line of openings | 7.5 | 40 | 5.5 |
| 4 | Between 0.15$L$ ~ 0.3$L$ from F.P. | Outside the line of openings | See note | | |
| | | Inside the line of openings | 7.5 | 40 | 5.5 |
| 5 | 0.4$L$ amidships | Outside the line of openings | 10.5 | – | – |
| | | Inside the line of openings | 7.5 | 40 | 5.5 |
| 6 | Between 0.075$L$ ~ 0.3$L$ from A.P. | Outside the line of openings | See note | | |
| | | Inside the line of openings | 7.5 | 40 | 5.5 |
| 7 | Aft of 0.07$L$ from A.P. | | 7.5 | 40 | 5.5 |

Note: The section modulus $W$ of deck longitudinals in way of the region may be determined after tapering the section moduli of amidships and end deck longitudinals.

2.8.5.2 The section modulus $W$ of cargo deck longitudinals (including longitudinals of decks/platforms within the engine room, fore and aft peaks) is not to be less than the following:

$$W = (2.5shl^2 + 0.6sL)K \quad \text{cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 5shl^2K \quad \text{cm}^3 \text{ for } L < 90 \text{ m}$$

where: $s$, $h$, $l$, $L$, $K$ — see those in 2.8.5.1 of this Section.

2.8.5.3 The section modulus $W$ of accommodation and superstructure deck longitudinals is not to be less than the following:

$$W = (2.5shl^2 + 0.52sL)K \quad \text{cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 4.4shl^2K \quad \text{cm}^3 \text{ for } L < 90 \text{ m}$$

where: $s$, $h$, $l$, $L$, $K$ — see those in 2.8.5.1 of this Section.

2.8.5.4 The web depth of deck longitudinals is in no case to be less than 60 mm.

2.8.5.5 The deck longitudinals outside the line of deck openings are to pass through deck transverses and to be connected to the deck transverse webs by welding. Where the deck longitudinals are cut in way of the web plates of hatch end beams or deck transverses (only for those inside the line of deck openings or at the ship's ends), brackets are to be fitted at the connection between deck longitudinals and hatch end beams or deck transverses and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of hatch end beams or deck transverses along the web plates of hatch end beams or deck transverses.

2.8.5.6 Where deck longitudinals are cut in way of transverse bulkheads, brackets are to be fitted at the connection between deck longitudinals and transverse bulkheads and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. Where the ship's length exceeds 200 m or higher tensile steel is adopted, the deck longitudinals outside the line of deck openings are to be continuous through the transverse bulkheads, but alternative arrangements may be considered.

2.8.5.7 The deck longitudinals outside the line of deck openings are not to be terminated at the same transverse section and their ends are to be suitably shifted from one another. These ends are to extend to the adjacent transverse members.

### 2.8.6 Longitudinal framing — deck girders

2.8.6.1 For deck girders supporting deck transverses, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck transverses and using an allowable bending stress of $124/K$, in N/mm$^2$.

2.8.6.2 The section moment of inertia $I$ of deck girders supporting deck transverses is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: $W$ — section modulus of deck girders, in cm$^3$, obtained according to 2.8.6.1 of this Section;

$l$ — span of deck girder, in m;

$K$ — material factor.

2.8.6.3 The thickness and cutouts of the web of deck girders supporting deck transverses are to comply with the relevant provisions in 2.8.3.6 and 2.8.3.7 of this Section respectively.

2.8.6.4 The connections between deck girders supporting deck transverses and transverse bulkheads are to comply with the relevant provisions of 2.8.3.8 of this Section.

### 2.8.7 Longitudinal framing — deck transverses

2.8.7.1 Where the deck is framed longitudinally, deck transverses supporting the deck longitudinals are to be fitted in line with plate floors. In general, the spacing of deck transverses is not to be greater than 3.6 m for ships of 100 m in length or less and not greater than $0.006L + 3.0$ m ($L$ being length of ship) for ships more than 100 m in length, In the forepeak and aft peak, the spacing of deck transverses is not to be greater than 2.5 m for ships of 100 m in length or less and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.8.7.2 In the machinery spaces and aft peak tank, deck transverses supporting deck longitudinals are to be fitted in frames spaces of web frames.

2.8.7.3 The section modulus $W$ of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: $S$ — spacing of deck transverses, in m;

$h$ — design head of deck, in m, to be determined according to 2.8.1.1 of this Section;

$l$ — span of deck transverses, in m;

$K$ — material factor.

2.8.7.4 The section modulus of deck transverses in single deck ships is to be 15% greater than that obtained from the formula in 2.8.7.3 of this Section.

2.8.7.5 Where the deck transverses supporting deck longitudinals are subject to concentrated loads, their increased section modulus may be determined by calculations in accordance with the requirements for deck girders in 2.8.3.3 or 2.8.3.4 of this Section.

2.8.7.6 The section moment of inertia $I$ of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: $W$ — section modulus of deck transverses, in m³, as required in this Section;

$l$ — span of deck transverses, in m;

$K$ — material factor.

2.8.7.7 The web depth of deck transverses is not to be less than 1.6 times the depth of cut-outs for the passage of deck longitudinals. The cutouts in deck transverses are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck transverses is not to be less than 1% of the web depth plus 4 mm.

2.8.7.8 Holes cut for the passage of pipes or cables in the web of deck transverses are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of deck longitudinals or the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of deck transverses. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the spacings of adjacent longitudinals. No holes are to be cut on the web of deck transverses within 200 mm from the bracket toe of deck transverses.

2.8.7.9 The ends of deck transverses are to be bracketed to frames or web frames or longitudinal bulkheads, and the scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART. Where the connection between deck transverses and web frames or longitudinal bulkhead vertical webs is designed as an integral structure, a ring system is generally to be formed and connecting brackets are to have the form of an circular arc with a radius generally not less than the web depth of deck transverses or web frames or longitudinal bulkhead vertical webs, whichever is the smallest. The brackets are to be provided with a face plate to connect the face plate of deck transverses and that of web frames or longitudinal bulkhead vertical webs, and the scantlings of the face plate are to be the same as those of the face plate of deck transverses.

### 2.8.8 Deck hatch side girders

2.8.8.1 Where weather deck hatch side girders (including weather deck hatch side coamings) act as deck girders and are supported at both ends of the hatchway, their section modulus $W$ and section moment of inertia $I$ are not to be less than those obtained from the following formulae respectively:

$$W = 7hbl^2K \quad \text{cm}^3$$

$$I = 2.6Wl/K \quad \text{cm}^4$$

where: $h$ — design head of deck, in m, see 2.8.1.1 of this Section;

$b$ — mean width, in m, of deck area supported by deck hatch side girders;

$l$ — span of deck hatch side girder, in m;

$K$ — material factor.

2.8.8.2 The section modulus W and section moment of inertia I of 'tween deck hatch side girders are not to be less than those obtained from the following formulae respectively:

$$W = 5.2hbl^2K \quad \text{cm}^3$$

$$I = 2Wl/K \quad \text{cm}^4$$

where: $h$ — design head of deck, in m, see 2.8.1.1 of this Section;

$b$ — mean width, in m, of deck area supported by 'tween deck hatch side girders;

$l$ — span of 'tween deck hatch side girder, in m;

$K$ — material factor.

2.8.8.3 Where 'tween deck hatch side girders are subject to concentrated loads, the section modulus is to be increased to 1.1 times that obtained according to 2.8.3.3 or 2.8.3.4 of this Section.

2.8.8.4 The depth of the web of deck hatch side girders below deck is not to be less than that of the beam web to which it is connected.

2.8.8.5 The thickness of the web of deck hatch side girders is not to be less than 1% of its depth plus 4 mm. The thickness and structure of hatch coamings are to comply with the requirements of 2.20.3.2 of this Chapter.

2.8.8.6 In the calculation of the section modulus and section moment of inertia of deck hatch side girders (including hatch coamings), the upper edge of the horizontal face plate (excluding holes in the face plate) of hatch coamings may be included; or only the upper edge of the horizontal stiffener is to be included if no horizontal face plate is fitted.

2.8.8.7 A gradual transition in depth is to be made for the extension of deck hatch side girders.

2.8.8.8 Where the deck is framed longitudinally, deck hatch side girders are to be bracketed to deck transverses. Where the web depth of deck hatch side girders below deck is the same as that of deck transverses, the girders and transverses are to be directly connected. Where the spacing of deck transverses is greater than two frame spaces, an additional tripping bracket is to be fitted between the transverses. This tripping bracket is to extend to the face plate of the deck hatch side girder and to the adjacent deck longitudinals. The thickness of the bracket is to be the same as that of the web plate of adjacent deck transverses, and the flange or face plate of the bracket is to comply with the provisions in 1.2.6.6 of Chapter 1 in this PART.

2.8.8.9 Where the deck is framed transversely, a bracket is to be fitted at the connection between each beam and deck hatch side girders. These brackets are to extend to the face plate of deck hatch side girders, and the scantlings of the brackets are to comply with the provisions in 1.2.6 of this PART.

### 2.8.9 Hatch end beams

2.8.9.1 Hatch end beams are to be fitted in accordance with the following requirements:

(1) Where a pillar complying with the requirements of Section 10 of this Chapter is fitted at each corner of the hatchway (i.e. hatch end beams do not support hatch side girders), the section modulus of hatch end beams is to meet the requirements of 2.8.2.1 of this Section, but in this case, $s$ in the formula is to be the actual width of deck area supported by hatch end beams.

(2) Where hatch end beams support the full load of hatch side girders, pillars are fitted below the beams at the longitudinal centerline of deck and deck longitudinal girders or longitudinal bulkheads are also fitted at the longitudinal centerline, hatch end beams are to be continuous within the breadth of ship and their section modulus $W$ and section moment of inertia $I$ are not to be less than those obtained from the following formulae respectively:

$$W = 4.6chAlK \quad \text{cm}^3$$

$$I = 3Wl/K \quad \text{cm}^4$$

where: $l$ — span of hatch end beams, in m;

$K$ — material factor;

$A$ — load area, in $m^2$, to be determined according to the following conditions:

① Where the deck is framed longitudinally and the extension of hatch side girders supports one or more deck transverses, see Figure 2.8.9.1(1):

$$A = F_1 + 2F_3 + F_4 + F_5$$

② Where the deck is framed longitudinally and the extension of hatch side girders does not support any deck transverse, see Figure 2.8.9.1(2):

$$A = F_1 + F_2 + F_3$$

③ Where the deck is framed transversely without additional girders, see Figure 2.8.9.1(3):

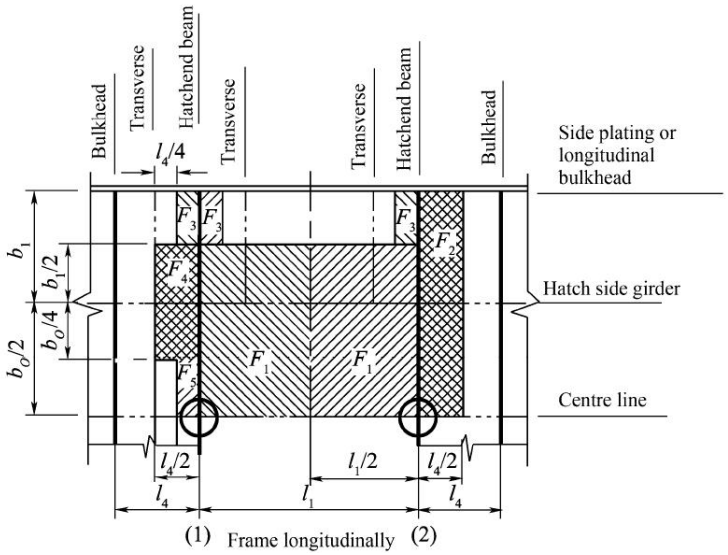
$$A = F_1 + F_4$$

④ Where the deck is framed transversely and with fitted with additional girders, see Figure 2.8.9.1(4):

$$A = F_1 + F_4;$$

$h$ — design head of deck, in m, see 2.8.1.1 of this Section;

$c$ — coefficient, to be taken according to the distance $a$ between the hatch side girder and the longitudinal centreline: $c$ = 1.6 for $a \geq l/2$ ($l$ being span of hatch end beams), $c$ = 1.5 for $a \leq l/3$, and $c$ is to be obtained by interpolation for $l/3 < a < l/2$.



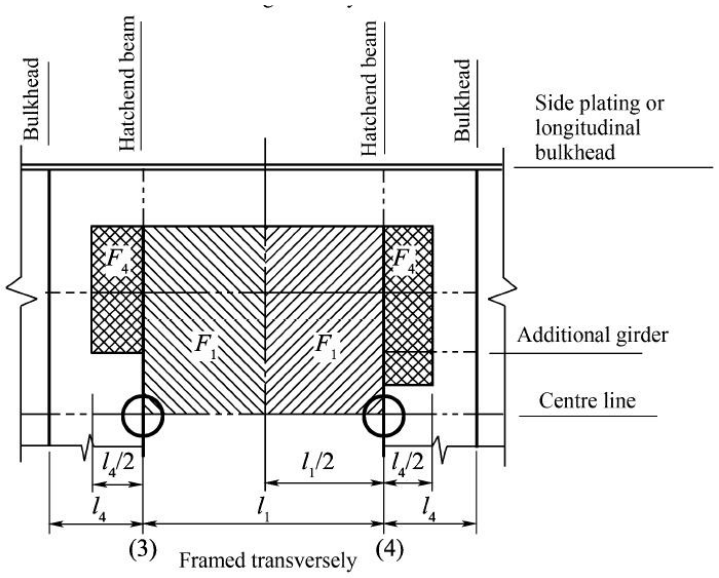



**Figure 2.8.9.1**

2.8.9.2 The connections between hatch end beams and frames or web frames or longitudinal bulkheads are to comply with the requirements of 2.8.7.9 of this Section.

# Section 9 CANTILEVERS

### 2.9.1 General requirements

2.9.1.1 Cantilevers covered by this Section are the deck transverses extending from ship side to the deck hatch side girders supported by them. The structural configuration of cantilevers and their supporting frames is as shown in Figure 2.9.1.1.

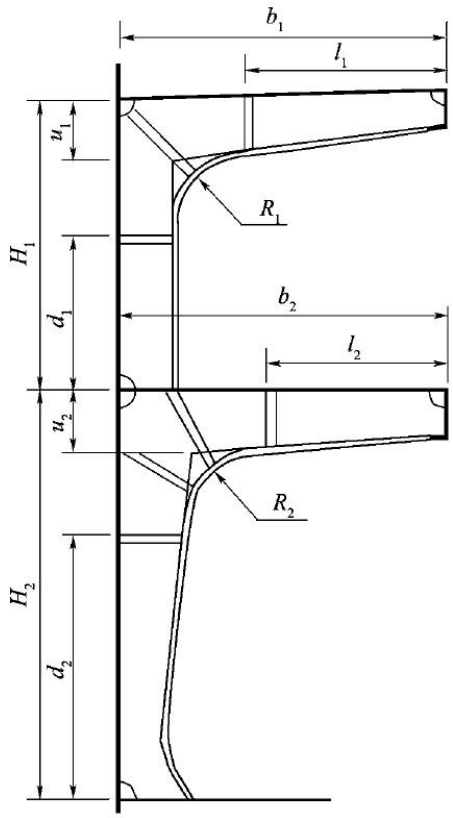



**Figure 2.9.1.1**

2.9.1.2 The considered sections of the cantilever and its supporting frame are to be the corresponding sections at the toe of the connecting bracket (i.e. at the tangential point of the arc of the bracket).

2.9.1.3 The requirements of this Section are applicable to ships having cantilevers approximately equally arranged, hatch side girders supported by cantilevers and uniform loading on decks and hatch covers.

### 2.9.2 Cantilevers

2.9.2.1 The section modulus $W_i$ of the considered section of cantilevers is not to be less than the respective values given below:

(1) Where cantilevers are not supported by hatch side girders:

$$W_i = 30.6Sl_i(l_i\, h_1 + b_0\, h_2)K \quad \text{cm}^3$$

where: $S$ — load width of cantilever, in m;

$l_i$ — span of cantilever, in m;

$b_0$ — width of hatch, in m;

$h_1$ — design head of deck outside the line of hatch openings, in m, see 2.8.1.1 of this Chapter;

$h_2$ — design head of deck or hatch cover inside the line of hatch openings, in m, see 2.8.1.1 or 2.20.2 of this Chapter;

$K$ — material factor.

(2) Where both ends of hatch side girders are fitted with the hatch end beams complying with the requirements of 2.8.9 of this Chapter and cantilevers are partially supported by hatch side girders:

$$W_i = W_0 - G \quad \text{cm}^3$$

where: $W_0 = 30.6\, S\, l_i(l_i\, h_1 + b_0\, h_2)K$ cm$^3$

where: $S$, $l_i$, $b_0$, $h_1$, $h_2$ — see (1) above;

$$G = \frac{8l_i}{(n+1)l_h}(W_h + W_P) \quad \text{cm}^3$$

where: $W_h$ — section modulus of the hatch side girder derived from 2.8.8.1 or 2.8.8.2 of this Chapter, in cm³, and the span of cantilevers taken as the spacing of cantilevers;

$W_p$ — section modulus of deck girders on the extension line of hatch side girders, in cm³, derived from 2.8.3 of this Chapter, and $W_p$ is to be taken not greater than $W_h$;

$n$ — number of cantilevers between hatch end beams;

$l_h$ — length of hatch, in m;

$l_i$ — span of cantilevers, in m.

(3) Where both ends of hatch side girders are supported by transverse bulkheads and cantilevers are partially supported by hatch side girders:

$$W_i = \frac{n+1}{n}\left[0.5\left(1+\frac{1}{Q}\right)W_o - QG - (1-Q)E\right] \quad \text{cm}^3$$

where: $W_o$, $G$, $n$ — see (2) above;

$$Q = \frac{l_h}{l_b};$$

where: $l_h$, $l_b$ — See Figure 2.9.2.1(1) of this Section;

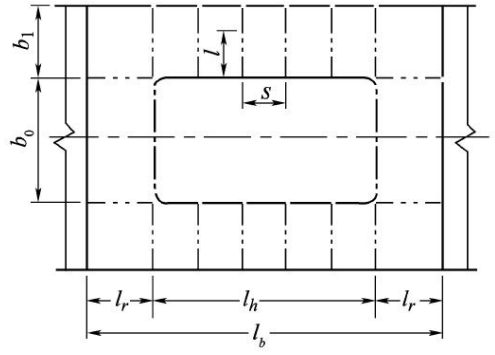
$E = \frac{4}{n+1}(W_1 + W_2)$ in cm³ for hatch end beams the midpoint of which is not supported by pillars, etc., or

$E = \frac{4}{n+1}\left[(W_1 + W_2) + \frac{2l_i}{b_o}(W_2 + W_3)\right]$ in cm³, for hatch end beams the midpoint of which is supported by pillars or bulkheads;

where: $W_1$, $W_2$ and $W_3$ are section module of hatch end beams, in cm³, as shown in Figure 2.9.2.1(2), $W_2$ is to be taken as the lesser of the section module of hatch end beams at both sides of the line of hatch openings;

$l_i$, $b_0$ — see Figure 2.9.2.1(1) of this Section.

And in addition, the section modulus $W_i$ of the cantilever is not to be less than that obtained from (2) above.



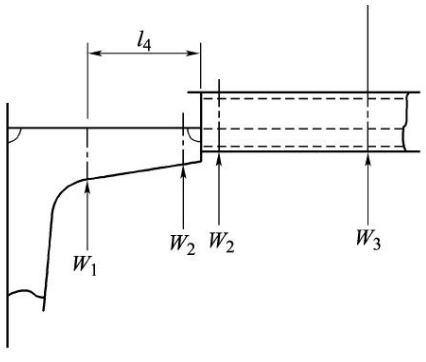



**Figure 2.9.2.1(1)** **Figure 2.9.2.1(2)**

(4) Where loading is concentrated at hatch side girders and cantilevers are partially supported by hatch side girders:

$$W_i = W'_0 - \frac{3.5 l_i}{S} W_h \quad \text{cm}^3$$

where: $W'_0$ — section modulus, in cm³, of the cantilever when subjected to concentrated loading and uniform loading, with no support from hatch side girders. In the calculation, the cantilever is to be assumed fixed at one end, and the allowable bending stress is to be taken as 115.2 N/mm²;

$l_i$, $S$, $W_h$ — see (1) and (2) above.

And in addition, the section modulus $W_i$ of the cantilever is not to be less than those obtained from (2) and (3) above.

2.9.2.2 The moment of inertia $I$ of the cantilever at the section under consideration is not to be less than that obtained from the following formula:

$$I = 9\ W_i l_i / K_i \quad \text{cm}^4$$

where: $W_i$ — section modulus of cantilevers, in cm³, derived from the formula in 2.9.2.1 of this Section;

$l_i$ — span of cantilevers, in m;

$K_i$ — material factor.

2.9.2.3 The net sectional area $A_x$ of the cantilever web is not to be less than that obtained from the following formula:

$$A_x = 0.43\ S\left(2 h_i X + b_o h_2 + \frac{0.283}{S} P_c\right)\frac{W_i}{W_o} \quad \text{cm}^2$$

where: $S$, $b_0$, $h_1$, $h_2$ — see 2.9.2.1(1) of this Section;

$X$ — distance, in m, between the section of cantilever under consideration and the hatch side girder;

$W_o$ — see 2.9.2.1(2) of this Section, in cm³;

$W_i$ — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

$P_c$ — concentrated loading, in kN, applied on the hatch side girder for calculation in accordance with 2.9.2.1(4) of this Section. $P_c$ = 0, if no concentrated loading is applied.

### 2.9.3 Supporting frames

2.9.3.1 The section modulus $W_{fi}$ at the considered section of supporting frames is not to be less than that obtained from the following formula:

$$W_{fi} = \frac{d_i}{H_i}\left[\frac{b_i}{l_i} W_i - W_{f(i-1)}\right] \quad \text{cm}^3$$

where: $d_i$, $H_i$, $b_i$, $l_i$ — see Figure 2.9.1.1 of this Section;

$W_{f(i-1)}$ — section modulus of supporting frames of the cantilevers on the $i-1$ tier deck, in cm³, and $W_{f(i-1)} = 0$ for the upper deck;

$W_i$ — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

$i$ — tier sign of decks, $i$ = 1 for upper deck, $i$ = 2 for 2nd tier deck and so on.

2.9.3.2 The scantlings of the supporting frames of the lower deck are, in general, not to be less than those of the supporting frames of the 'tween deck above.

### 2.9.4 Structural requirements

2.9.4.1 Cantilevers and supporting frames are to be connected by brackets. The radius of the arc of the bracket is not to be less than $u_i$. The sectional area of the face plate and the web thickness of the bracket are not to be less than those of the larger one of connected members. Tripping brackets are to be fitted at the toes of the brackets (i.e. in way of the considered section of the cantilever and supporting frame), and an adequate number of stiffeners is to be fitted to the web connecting the bracket. See Figure 2.9.1.1.

2.9.4.2 Where the deck is framed longitudinally, cantilevers are to be provided with tripping brackets in accordance with the requirements of 1.2.5.4 of this PART; where the deck is framed transversely, the tripping brackets of cantilevers are to be generally spaced 3 m apart.

2.9.4.3 The minimum thickness of the web plate of cantilevers and supporting frames is not to be less than 1% of the web depth plus 4.5 mm. Where the web depth is greater than 700 mm, vertical stiffeners are to be fitted and spaced not greater than 1.5 times the web depth apart.

2.9.4.4 The web depth and the sectional area of face plates of cantilevers and supporting frames may be gradually tapered from the considered section to the ends, but the minimum web depth at ends is not to be less than 50% of the web depth at the considered section, and the sectional area of face plates at ends is not to be less than 60% of that at the considered section. Longitudinals passing through cantilevers and supporting frames are, in addition, to comply with the relevant requirements of 2.8.7.7 of this Chapter.

2.9.4.5 The effective area of the attached plating of cantilevers and supporting frames is to be calculated according to the requirements of 1.2.2.1 of this PART.

2.9.4.6 Where cantilevers and supporting frames consist of two or three combined members having a T-shaped cross section, they are to be regarded as a single cantilever, and the section modulus of such combined cantilevers is to be determined according to 2.9.2.1 of this Section, and the individual modulus of each cantilever is then determined by dividing this modulus by the actual number of cantilevers.

2.9.4.7 The supporting frames in holds are to be securely connected to the inner bottom by brackets. Plate floors or other stiffening arrangements are to be provided in the double bottom in line with cantilevers and supporting frames.

2.9.4.8 The web depth of hatch side girders below the deck is in general not to be less than that of the web plate at the end of cantilevers. Cantilevers and hatch side girders are to be securely connected with each other.

## Section 10 PILLARS

### 2.10.1 Load supported by pillars

2.10.1.1 The load $P$ supported by the pillar is to be calculated according to the following formula:

$$P = 7.06abh + P_0 \quad \text{kN}$$

where: $a$ — length of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

$b$ — mean width of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

$h$ — design head of the deck supported by the pillar, in m, see 2.8.1.1 of this Chapter;

$P_0$ — load transmitted from the pillar above, in kN.

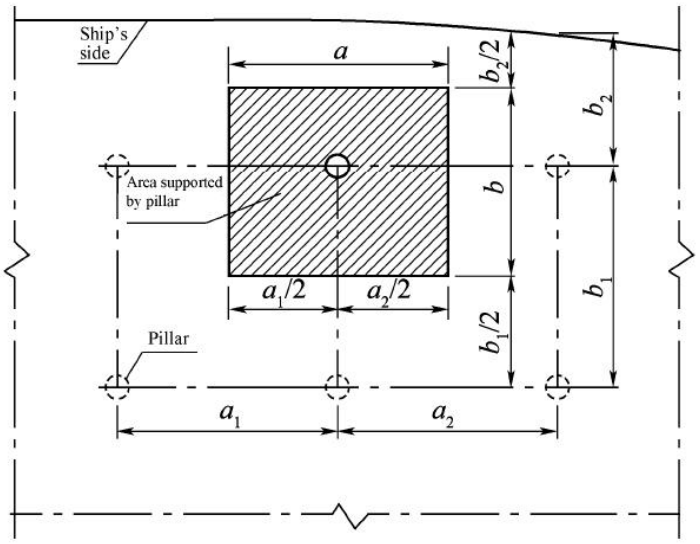



**Figure 2.10.1.1**

### 2.10.2 Cross-sectional area of pillars

2.10.2.1 The cross-section area $A$ of pillars is not to be less than that obtained from the following formula:

$$A = \frac{KP}{12.26 - 5.10\dfrac{l}{r\sqrt{K}}} \quad \text{cm}^2$$

where: $P$ — load on the pillars, in kN;

$l$ — the effective length of pillars, in m, to be taken as 0.8 times the whole length of pillars;

$r$ — minimum radius of gyration of the cross section of pillars, in cm;

$K$ — material factor, but it is not to be taken less than 0.72.

### 2.10.3 Minimum wall thickness of pillars

2.10.3.1 The wall thickness $t$ of tubular pillars is not to be less than the following:

$$t = \frac{P}{0.392d_p - 4.9l} \quad \text{mm}$$

$$t = \frac{d_p}{40} \quad \text{mm}$$

where: $P$ — load on the pillars, in kN, see 2.10.1.1 of this Section;

$l$ — see 2.10.2.1 of this Section;

$d_p$ — mean diameter of tubular pillars, in mm.

The minimum wall thickness of tubular pillars is to be 5 mm for ship's length $L < 60$ m; 6 mm for 60 m $\le L <$ 90 m and 7 mm for $L \ge 90$ m.

2.10.3.2 The built or rolled-section pillars are to comply with the following requirements:

(1) The wall thickness $t$ of hollow rectangular pillars or the web thickness $t$ of I-shaped or channel-section pillars is not to be less than the lesser of the following:

$$t = \frac{br}{60l} \quad \text{mm}$$

$$t = \frac{b}{55} \quad \text{mm}$$

where: $b$ — length of hollow rectangular pillars or web depth of I-shaped or channel-section pillars, in mm;

$l$, $r$ — see 2.10.2.1 of this Section.

The minimum wall thickness of hollow rectangular pillars or the minimum web thickness of I-shaped or channel-section pillars is not to be less than 5 mm for ship's length $L < 60$ m, 6 mm for 60 m $\leq L <$ 90 m and 7 mm for $L \geq 90$ m.

(2) The side thickness $t$ of angular pillars and the face plate thickness $t$ of channel-section pillars are not to be less than the lesser of the following:

$$t = \frac{br}{20l} \quad \text{mm}$$

$$t = \frac{b}{18} \quad \text{mm}$$

where: $b$ — side length of angular pillars or face plate breadth of channel-section pillars, in mm;

$l$, $r$ — same as defined in 2.10.2.1 of this Section.

(3) The thickness $t$ of face plate of I-shaped pillars is not to be less than the lesser of the following:

$$t = \frac{br}{40l} \quad \text{mm}$$

$$t = \frac{b}{36} \quad \text{mm}$$

where: $b$ — breadth of face plate of I-shaped pillars, in mm;

$l$, $r$ — same as defined in 2.10.2.1 of this Section.

### 2.10.4 Strengthening of structures at heads and heels of pillars

2.10.4.1 The structures at the heads and heels of pillars are to be so arranged that loads are reasonably supported and transmitted. Tubular and hollow rectangular pillars are to be attached at their heads to plates supported by efficient brackets. Longitudinal and transverse brackets are to be fitted at the heads and heels of the built or rolled-section pillars. Doubler or insert plates are to be fitted below pillars.

2.10.4.2 Pillars are to be fitted on plate floors or girders, and these plate floors or girders are to be fitted with vertical stiffeners. Widely spaced pillars are to be fitted at the intersection of plate floors and girders and if they are not fitted at the intersection, partial floors or girders are to be fitted below such pillars. Manholes are not to be cut in the floors and girders below pillars.

2.10.4.3 Where pillars are fitted on a shaft tunnel or any weak framing, structural strengthening is required in way of the pillars.

2.10.4.4 For pillars fitted inside ballast tanks or other tanks, attention is to be given to the effects of possible tensions.

2.10.4.5 Tubular or hollow rectangular pillars are not to be used inside oil tanks.

# Section 11 NON-WATERTIGHT PILLAR BULKHEADS

### 2.11.1 General requirements

2.11.1.1 The minimum thickness of bulkhead plating is to be 7 mm in lower holds and 6 mm in 'tween decks and where the ship's length is less than 90 m, the minimum thickness is to be 5 mm.

2.11.1.2 The maximum spacing of bulkhead stiffeners is to be 1,500 mm.

2.11.1.3 The sectional area $A$ of bulkhead stiffeners (including attached plating not exceeding 600 mm in width), which support beams, longitudinals, girders, transverses, etc., is not to be less than the following:

$$A = \frac{KP}{12.26 - 5.1\frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \leq 80$$

$$A = \frac{KP}{4.86 - 1.475\frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \geq 120$$

$A$ is to be obtained by interpolation for $80 < \frac{s}{t} < 120$

where: $P$, $r$ — see 2.10.2.1 of this Chapter;

$l$ — span of stiffeners, in m;

$s$ — spacing of stiffeners, in mm;

$t$ — thickness of bulkhead plating, in mm;

$K$ — material factor, to be taken not less than 0.72.

2.11.1.4 The minimum web depth of stiffeners is to be 150 mm in lower holds and 100 mm in 'tween decks and where the ship's length is less than 90 m, the minimum depth is to be 100 mm and 75 mm respectively.

# Section 12 WATERTIGHT BULKHEADS

### 2.12.1 General requirements

2.12.1.1 Watertight bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 8, Chapter 1 of this PART.

2.12.1.2 The total number of transverse watertight bulkheads is, in general, not to be less than that given in Table 2.12.1.2. For ships over 190 m in length, this number is to be determined by direct calculation.

**Total Number of Watertight Bulkheads** **Table 2.12.1.2**

| Ship's length / Ship type | $L \leq 60$ | $60 < L \leq 85$ | $85 < L \leq 105$ | $105 < L \leq 125$ | $125 < L \leq 145$ | $145 < L \leq 165$ | $165 < L \leq 190$ |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Machinery amidships | 4 | 4 | 5 | 6 | 7 | 8 | 9 |
| Machinery aft | 3 | 4 | 5 | 6 | 6 | 7 | 8 |

2.12.1.3 Transverse watertight bulkheads are to be fitted in accordance with the following requirements:

(1) All watertight bulkheads are to extend to the bulkhead deck, except collision bulkheads and after peak bulkheads.

(2) The bulkheads in the holds are to be spaced at uniform intervals. Where the length of a hold is greater than 0.15$L$ or 30 m, whichever is the greagter, transverse structures are to be strengthened and relevant supporting documents are to be submitted.

(3) Where it is impracticable for the arrangement of watertight bulkheads to comply with Table 2.12.1.2 due to the requirements of a special trade, one or more of these bulkheads may be dispensed with, subject to suitable structural compensation and demonstration by direct calculation that the transverse strength is adequate.

2.12.1.4 Where the bulkheads form the boundaries of deep tanks, the bulkhead structures are also to satisfy the requirements of Section 13 of this Chapter for the deep tank bulkheads.

2.12.1.5 The bulkheads may be of the plane, symmetrically corrugated or double-plated type.

### 2.12.2 Collision bulkhead

2.12.2.1 For the calculation of structural members of collision bulkheads, the value $h$ is to be 1.25 times the height required accordingly.

### 2.12.3 Plane bulkhead plating

2.12.3.1 The thickness $t$ of the plane watertight bulkhead plating is not to be less than that obtained from the following formula, nor less than 5.5 mm:

$$t = 4s\sqrt{hK} \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the lower edge of the plate in a strake to the bulkhead deck at side, to be taken as not less than 2.5 m;

$K$ — material factor.

2.12.3.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm, and the thickness of bulkhead plating in way of the passage of the stern tube is to be doubled.

2.12.3.3 The lowest strake of bulkheads is not to be less than 900 mm in height measured from the inner bottom, or from the bottom in the case of single bottom. Where a double bottom is provided on one side and a single bottom on the other side of the bulkhead, the lowest strake is to extend at least 300 mm above the flat portion of the double bottom.

2.12.3.4 Where the difference in thickness between the bulkhead and the web of longitudinal girders attached to the bulkhead is too great, the thickness of bulkhead plating in way is to be increased.

### 2.12.4 Plane bulkhead stiffeners

2.12.4.1 The section modulus $W$ of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad cm^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the mid-span of stiffeners to the bulkhead deck at side, but not to be taken as less than 2 m;

$l$ — span of stiffener, in m;

$C$ — coefficients, to be taken as follows:

$C = 6$, for stiffeners unattached at both ends, or directly attached to unstiffened plating;

$C = 3$, for stiffeners bracketed at ends; stiffeners directly lapped to longitudinal members at ends; stiffeners directly connected to longitudinally framed deck plating (inner bottom) at ends, and the stiffeners are in line with the webs of longitudinals; stiffeners directly connected to deck plating or girder web at ends, provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

$K$ — material factor.

2.12.4.2 Where a transverse bulkhead supports deck girders, bulkhead stiffeners are to be fitted in way of the deck girders. The sectional area of these stiffeners together with attached plating is also to comply with the requirements of Section 11 of this Chapter for non-watertight pillar bulkheads.

2.12.4.3 The scantlings of end brackets of bulkhead stiffeners are to comply with the provisions in 1.2.6 of this PART. Stiffeners unattached at ends are applicable only in the upper 'tween deck spaces.

2.12.4.4 The brackets at the ends of stiffeners are to be extended and efficiently welded to the beams or floors adjacent to the bulkhead respectively. Where the deck or bottom is framed longitudinally and where the brackets at ends of stiffeners are not in line with longitudinals, stiffening bars are to be fitted between the ends of brackets and longitudinals.

2.12.4.5 The minimum web depth of stiffeners is to meet the requirements of 2.11.1.4 of this Chapter, and the thickness t of the web is to meet the following requirements:

$t \geq \frac{d_w}{60\sqrt{K}}$ mm for rolled or combined stiffeners with flange or face plate

$t \geq \frac{d_w}{18\sqrt{K}}$ mm for flat bar stiffeners

where: $d_w$ — depth of stiffener webs, in mm;

$K$ — material factor.

### 2.12.5 Bulkheads with symmetrical corrugations

2.12.5.1 Symbols for the dimensions of corrugations are as shown in Figure 1.2.4.3, Chapter 1 of this PART.

2.12.5.2 Dimensions of corrugations are to comply with the following requirements:

(1) The section modulus $W$ of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad \text{cm}^3$$

where: $l$ — span of corrugation, in m;

$h$ — vertical distance, in m, measured from the mid-span of the corrugation to the bulkhead deck at side, but not to be taken as less than 2 m;

$s$ — spacing of corrugations, in m;

$C$ — coefficient, to be taken according to the end fixity as specified in Table 2.12.5.2;

$K$ — material factor.

(2) The angle $\alpha$ between web and flange of corrugations is not to be less than 40°.

(3) Where the span of corrugation exceeds 15 m, a diaphragm plate is to be arranged near the mid-span or equivalent measures for strengthening are to be taken.

**Value of Coefficient *C*** **Table 2.12.5.2**

| Upper end / Lower end | Directly connected to deck | As shown in Figure 2.12.5.2(2) or (3) |
|---|---|---|
| As shown in Figure 2.12.5.2(1) or (2) or (3) | 5.04 | 3.84 |

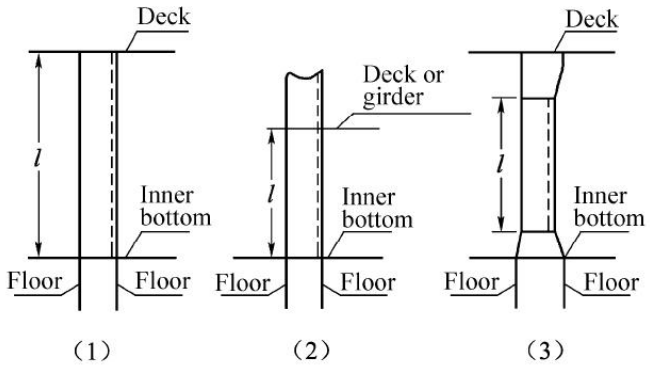



**Figure 2.12.5.2**

2.12.5.3 The plating thickness $t$ of bulkheads with symmetrical corrugations is to comply with the requirements of 2.12.3.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{85\sqrt{K}} \quad \text{mm} \qquad \text{at top}$$

$$t \geq \frac{a}{70\sqrt{K}} \quad \text{mm} \qquad \text{at bottom}$$

where: $a$ — width of corrugation flange, in mm;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

2.12.5.4 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than $0.2l$ above the mid-span.

### 2.12.6 Double plate bulkheads

2.12.6.1 The section modulus $W$ of webs of double plate bulkheads is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad cm^3$$

where: $s$ — spacing of webs, in m, see Figure 1.2.4.4 of Chapter 1 of this PART;

$h$ — vertical distance, in m, measured from the mid-span to the bulkhead deck at side, but to be taken as not less than 2 m;

$l$ — span of webs, in m;

$C$ — coefficient, to be taken according to the end fixity as specified in Table 2.12.6.1;

$K$ — material factor.

**Value of coefficient *C*** **Table 2.12.6.1**

| Upper end / Lower end | Directly connected to deck | As shown in Figure 2.12.5.2(2) or (3) |
|---|---|---|
| As shown in Figure 2.12.5.2(1) or (2) or (3) | 3.96 | 3.00 |

2.12.6.2 The scantlings of double plate bulkheads are to comply with the requirements of 2.12.3.1 and 2.12.6.1 of this Section and in addition, the following requirements:

(1) The plating thickness $t_p$ of double plate bulkheads is to comply with the following requirements:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad mm \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad mm \quad \text{at bottom}$$

where: $s$ — spacing of webs, in mm;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

(2) The plating thickness $t_w$ and the shear area $A_w$ of the web of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad mm \quad \text{at top}$$

$$A_w \geq 0.12\frac{W}{l} \quad cm^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad mm \quad \text{at bottom}$$

$$A_w \geq 0.18\frac{W}{l} \quad cm^2$$

where: $b$ — spacing of plates of double plate bulkheads, in mm;

$W$ — section modulus required in 2.12.6.1 of this Section, in cm³;

$l$ — span of webs, in m;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower

strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

2.12.6.3 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than $0.2l$ above the mid-span. Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

### 2.12.7 Girders

2.12.7.1 The section modulus $W$ of girders is not to be less than that obtained from the following formula:

$$W = 6.6bhl^2K \quad \text{cm}^3$$

where: $b$— breadth of the area supported by the girder, in m;

$h$— vertical distance, in m, measured from the mid-span of girders to the bulkhead deck at side, but to be taken not less than 2 m;

$l$ — span of girder, in m;

$K$— material factor.

2.12.7.2 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.12.7.3 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART.

### 2.12.8 Watertight bulkhead steps

2.12.8.1 The section modulus $W$ of beams of decks or flats forming the steps in bulkheads is not to be less than that obtained from the following formula:

$$W = 4.2shl^2K \quad \text{cm}^3$$

where:

$s$ — spacing of beams, in m;

$h$ — vertical distance, in m, measured from the deck or flat forming bulkhead steps to the bulkhead deck at side, but to be taken not less than 2 m;

$l$ — span of beams, in m, but to be taken not less than 2 m;

$K$ — material factor.

2.12.8.2 The thickness of plating of the deck or flat forming the steps in bulkheads is to be 1 mm thicker than that required in 2.12.3.1 of this Section, and in this case $s$ in the formula is to be taken as the spacing of beams.

2.12.8.3 The thickness of plating of the deck or flat forming the steps in bulkheads and the scantlings of beams are in no case to be less than those required, as appropriate, in Sections 4 and 8 of this Chapter for deck plating and beams.

# Section 13 DEEP TANKS

### 2.13.1 General requirements

2.13.1.1 The deep tanks referred to in this Section are those loaded with liquids, such as water, oil fuel, vegetable oil, spoil, etc., which form a part of hull within tank or 'tween deck.

2.13.1.2 For ballast tanks with ballast water exchange by overflow method, the design pressure head $h$ is, in addition to complying with the requirements of this Section, not to be less than the vertical distance from the calculation point to the overflow point.

### 2.13.2 Plane bulkheads

2.13.2.1 The thickness $t$ of plane bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.95 s \sqrt{\rho h K} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the lower edge of the plate in a strake to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$K$ — material factor.

The thickness of bulkhead plating is not to be less than 8 mm for $L \geq 90$ m; not to be less than 7 mm for 60 m $\leq L <$ 90 m; and not to be less than 6 mm for $L <$ 60 m.

2.13.2.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm.

2.13.2.3 The section modulus $W$ of stiffeners of bulkheads is not to be less than that obtained from the following formula:

$$W = 8 s \rho h l^2 K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m;

$h$ — vertical distance, in m, measured from the mid-span of the stiffener to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater. The ends of stiffeners are to be connected by brackets, and the scantlings of these brackets are to be in accordance with the relevant requirements in 1.2.6 of this PART. The ends of the stiffeners may also be connected directly to the deck plating or girders provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$K$ — material factor.

The section moment of inertia $I$ of stiffeners is not to be less than that obtained from the following formula:

$$I = 2.3 W l / K \quad \text{cm}^4$$

where: $W$, $l$ — same as defined above.

### 2.13.3 Bulkheads with symmetrical corrugations

2.13.3.1 The scantlings of the bulkheads are to be in accordance with the following requirements:

(1) The section modulus $W$ of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Cs\rho hl^2K \quad \text{cm}^3$$

where: $l$ — span of stiffener, in m;

$h$ — vertical distance, in m, measured from the mid-span of the corrugation to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$s$ — spacing of corrugation, in m;

$C$ — coefficient, to be taken according to the end fixity as specified in Table 2.13.3.1;

$K$ — material factor.

**Value of coefficient *C*** **Table 2.13.3.1**

| Upper end / Lower end | Directly connected to deck | As shown in Figure 2.12.5.2(2) or (3) of this Chapter |
|---|---|---|
| As shown in Figure 2.12.5.2(1) or (2) or (3) of this Chapter | 13.3 | 10.3 |

(2) The angle α between web and flange of corrugations is not to be less than 40°.

(3) Where the span of corrugations exceeds 15 m, a horizontal girder is to be arranged near the mid-span.

2.13.3.2 The plating thickness $t$ of corrugated bulkheads is to comply with the requirements of 2.13.2.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{70\sqrt{K}} \quad \text{mm}$$

where: $a$ — width of corrugation flange, in mm;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

2.13.3.3 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than 0.2$l$ above the mid-span.

### 2.13.4 Double plate bulkheads

2.13.4.1 The section modulus $W$ of webs and the spacing $b$ of plates of double plate bulkheads are not to be less than those obtained from the following formulae:

$$W = Cs\rho hl^2K \quad \text{cm}^3$$

$$b = 40l \quad \text{mm}$$

where: $s$ — spacing of webs, in m;

$h$ — vertical distance, in m, measured from the mid-span to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of web, in m;

$C$ — coefficient, to be taken according to the end fixity as specified in Table 2.13.4.1;

$K$ — material factor.

**Value of coefficient *C*** **Table**

**2.13.4.1**

| Upper end / Lower end | Directly connected to deck | As shown in Figure 2.12.5.2(2) or (3) of this Chapter |
|---|---|---|
| As shown in Figure 2.12.5.2(1) or (2) or (3) of this Chapter | 10.2 | 8 |

2.13.4.2 The plating thickness $t_p$ of double plate bulkheads is to comply with the requirements of 2.13.2.1 of this Section and in addition, the following formulae are to be complied with:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: $s$ — spacing of webs, in mm;

$K$— material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.9.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

2.13.4.3 The plating thickness $t_w$ and shear area $A_w$ of webs of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$A_w \geq 0.07\frac{W}{l} \quad \text{cm}^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

$$A_w \geq 0.10\frac{W}{l} \quad \text{cm}^2$$

where: $b$ — spacing of plates of double plate bulkheads, in mm;

$W$ — section modulus required in 2.13.4.1 of this Section, in cm³;

$l$ — span of webs, in m;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

2.13.4.4 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than 0.2$l$ above the mid-span.

Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

### 2.13.5 Girders

2.13.5.1 The section modulus $W$ of girders is not to be less than that obtained from the following formula:

$$W = 11.7bph l^2 K \quad \text{cm}^3$$

where: $b$ — breadth of the area supported by the girder, in m;

$h$ — vertical distance, in m, measured from the mid-span of girder to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of girder, in m;

$K$ — material factor.

2.13.5.2 The section moment of inertia $I$ of girders is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ — same as defined in 2.13.5.1 of this Section.

2.13.5.3 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.13.5.4 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of the brackets are to comply with the relevant provisions in 1.2.7 of this PART.

### 2.13.6 Transverse side framing

2.13.6.1 Frames are to comply with the following requirements:

(1) The section modulus of frames other than those of forepeak and aft peak tanks is to be increased by 15% above that required in Section 7 of this Chapter.

(2) The section modulus $W$ and section moment of inertia $I$ of frames are to be not less than those obtained from the following formulae in addition to the requirement mentioned above:

$$W = 6.8s\rho hl^2K \quad \text{cm}^3$$

$$I = 3.5Wl/K \quad \text{cm}^4$$

where: $s$ — spacing of frames, in m;

$l$ — span of frame, in m, the vertical distance measured from the upper edge of floor or inner bottom to the side stringer, or between side stringers or from the side stringer to the ’tween deck;

$h$ — vertical distance, in m, measured from the mid-span of frame to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$K$ — material factor.

(3) The arm length of end brackets of frames is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.6.2 Side stringers supporting the frames are to comply with the requirements of 2.13.5.3 to 2.13.5.4 of this Section and in addition, to have a section modulus $W$ and a moment of inertia $I$ not less than those obtained from the following formulae:

$$W = 11.7b\rho hl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $b$ — breadth of the area supported by the stringer, in m;

$h$ — vertical distance, in m, from the mid-span of stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, but not less than the distance measured from the mid-span of stringer to the upper deck, or to a point

1.4$d$ ($d$ being the draught, in m) above the plate keel, whichever is the lesser;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of stringer, in m;

$K$ — material factor.

2.13.6.3 In deep tanks forward of 0.2$L$ from F.P., side stringers are to be fitted and spaced not more than 5 m apart, or perforated flats having scantlings complying with the requirements of 2.15.1.11 of this Chapter are to be fitted. Where the length of the tank exceeds 14 m and perforated flats are fitted in lieu of the side stringers, web frames or transverse wash bulkheads are to be fitted.

2.13.6.4 The scantlings of web frames supporting the side stringers are to be calculated according to 2.7.4.1 of this Chapter. But the design head $h$ is to be taken as the vertical distance measured from the side stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, in m; but not to be less than the distance measured from stringers to the upper deck or to a point 1.4$d$ ($d$ being the draught, in m) above the plate keel, whichever is the lesser.

### 2.13.7 Longitudinal side framing

2.13.7.1 In addition to complying with the requirements of Section 7 of this Chapter, the section modulus $W$ of side longitudinals is not to be less than that obtained from the following formula:

$$W=8.8s\rho hl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$h$ — vertical distance, in m, measured from the longitudinal to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of longitudinal, in m;

$K$ — material factor.

The end connections of side longitudinals are to comply with the relevant requirements of 2.7.5.7. The arm length of the end brackets is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.7.2 The section modulus $W$ of the web frames supporting the side longitudinals is not to be less than that obtained from the following formula:

$$W=11.7s\rho hl^2K \quad \text{cm}^3$$

where: $s$ — spacing of web frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of web frame to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of web frame, in m;

$K$ — material factor.

2.13.7.3 The section moment of inertia $I$ of web frames is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ — same as defined in 2.13.7.2 of this Section.

2.13.7.4 In deep tanks forward of 0.2$L$ from F.P., the section modulus of web frames supporting the side longitudinals is to be increased by 20% above that obtained from 2.13.7.2 of this Section.

In general, the spacing of web frames is not to be greater than 3.0 m for ships of 100 m in length or less and not greater than 4.2 m for ships of 300 m or over in length, and the intermediate values are to be obtained by interpolation. Where the depth of the tank exceeds 16 m, perforated flats are to be fitted, and transverses are to be fitted in way of the web frames.

### 2.13.8 Deck plating and framing

2.13.8.1 In addition to complying with the requirements of Section 4 of this Chapter, the plating thickness $t$ of the deck (or flat) of deep tanks is not to be less than that obtained from the following formula:

$$t = 3.95s\sqrt{\rho hK} + 3.5 \quad \text{mm}$$

where: $s$ — spacing of frames, in m;

$h$ — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$K$ — material factor.

The plating thickness $t$ of the deck (or flat) is not to be less than 8 mm for ship's length $L \geq 90$ m; 7 mm for 60 m $\leq L <$ 90 m; 6 mm for $L <$ 60 m.

2.13.8.2 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus $W$ of longitudinals or beams of the decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 8.8s\rho hl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals or beams, in m;

$h$ — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of longitudinal or beam, in m;

$K$ — material factor.

The section moment of inertia $I$ is not to be less than that obtained from the following formula:

$$I = 2.3Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ — same as defined above.

2.13.8.3 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus $W$ of girders or transverses of decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 11.7S\rho hl^2K \quad \text{cm}^3$$

where: $S$ — spacing of girders or transverses, in m;

$h$ — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of the overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$l$ — span of girder or transverse, in m;

$K$ — material factor.

The section moment of inertia $I$ is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ — same as defined above.

2.13.8.4 The web depth of deck girders or transverses is to comply with the relevant requirements of Section 8 of this Chapter.

2.13.8.5 In deep tanks forward of 0.2$L$ from F.P., the spacing of deck transverses supporting the deck longitudinals is to be the same as that of web frames as provided in 2.13.7.4 of this Section.

### 2.13.9 Bottom framing

2.13.9.1 The transversely framed single bottom in deep tanks forward of 0.2$L$ from F.P. is to comply with the following requirements:

(1) Plate floors are to be fitted at every frame space, and the scantlings of floors are not to be less than those required in 2.15.1.1 of this Chapter. In way of web frames, the depth of floors and scantlings of face plates are not to be less than those of web frames.

(2) The section modulus $W$ of the centerline girder is not to be less than the greater of those obtained from the following formulae:

$$W=9s\,h_1\,l^2K \quad \text{cm}^3$$

$$W=9.8s\rho\,h_2\,l^2K \quad \text{cm}^3$$

where: $s$ — mean spacing supported by centerline girder, in m;

$l$ — span of centerline girder, in m;

$h_1$ — vertical distance, in m, measured from the mid-span to upper deck at side; for the region forward of 0.15$L$ from F.P., to 3 m above the deck for measuring minimum bow height (see Regulation 39 of the International Convention on Load Lines, 1966);

$h_2$ — vertical distance, in m, measured from the mid-span to the top of the deep tank, or half the vertical distance to the top of overflow, whichever is the greater;

$\rho$ — density of liquid, in t/m$^3$, to be taken not less than 1.025;

$K$ — material factor.

The section moment of inertia $I$ is not to be less than that obtained by the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ — same as defined above.

(3) Intercostal side girders are to be fitted and spaced not more than three frame spaces apart. The scantlings of intercostal side girders are to be the same as those of floors.

2.13.9.2 For longitudinally framed single bottom in deep tanks forward of 0.2$L$ from F.P., the spacing of plate floors supporting longitudinals is to be the same as that of the web frames as provided in 2.13.7.4 of this Section. The plate floors are to be supported by a continuous centreline girder or a longitudinal bulkhead. The scantlings of plate floors and centreline girders are to comply with the relevant requirements of Section 3, Chapter 6 of this PART.

### 2.13.10 Wash bulkheads

2.13.10.1 Where a deep tank extends from side to side of the ship, a longitudinal bulhead or wash bulkhead is to be fitted on the centreline. Where the widest breadth of the tank exceeds 0.5$B$ within the region forward of 0.3$L$ from F.P., a wash bulkhead is to be fitted on the centreline of the tank. Where the widest breadth of the tank exceeds 0.7$B$, it is recommended that a longitudinal bulkhead be fitted on the centreline of the tank.

2.13.10.2 The thickness of the wash bulkhead is to be the same as that required for the bulkheads mentioned in this Section. The section modulus of the stiffeners of the wash bulkhead is to be equal to 50% of that of those bulkheads, but $h$ is to be measured to the top of the deep tank. The stiffeners are to be connected by brackets at both ends. The area of perforations is not to be less than 5% nor more than 10% of the total area of the bulkhead.

# Section 14 STEMS, STERN FRAMES, BULBOUS BOWS AND PROPELLER SHAFT BRACKETS

### 2.14.1 Stems

2.14.1.1 The cross-sectional area $A$ of bar stems up to 0.5 m above the summer load waterline is not to be less than the following:

$$A = 1.2L \quad \text{cm}^2 \text{ for } L < 90 \text{ m}$$
$$A = 1.63L - 38 \quad \text{cm}^2 \text{ for } L \geq 90 \text{ m}$$

where: $L$ — length of ship, in m.

From a position above 0.5 m from the summer load waterline, the cross-sectional area may be gradually tapered to the stem head where the area may be reduced by 25%.

2.14.1.2 The thickness $t$ of plate stems up to 0.5 m above the summer load waterline is not to be less than that obtained from the following formula:

$$t = (0.08L + 5.5)\sqrt{K} \quad \text{mm}$$

where: $L$ — length of ship, in m, but not to be taken greater than 230 m;

$K$ — material factor.

From a position above 0.5 m from the summer load waterline, the plate thickness may be gradually tapered to the stem head where the thickness may be the same as that of the shell at ends.

Plate stems are to be supported by horizontal webs spaced not more than 1 m apart, and the web thickness is not to be less than the thickness of the adjacent shell plating. The webs are to be extended aft to be connected to frames or side stringers, but at least beyond the butts of stem plates and shell plating.

Where the radius of curvature of the stem is large, a centreline vertical web is to be fitted, having the same thickness as the horizontal webs.

2.14.1.3 Cast steel stems are to be easy for manufacture, and all fillets are to have adequate radii. The sectional area of cast steel stems is not to be less than that of bar stems required in 2.14.1.1 of this Section. Cast steel stems are to be provided with rib reinforcement.

### 2.14.2 Stern frames without rudder post

2.14.2.1 The stern frame without rudder post is composed of sole piece, propeller post and propeller boss.

2.14.2.2 The scantlings of fabricated propeller posts (as shown in Figure 2.14.2.2) are not to be less than those obtained from the following formulae:

Length of stern frame: $a = 46\sqrt{L}$ mm

Thickness of stern frame: $t = 2.3\sqrt{L} + 3$ mm

where: $L$ — length of ship, in m.

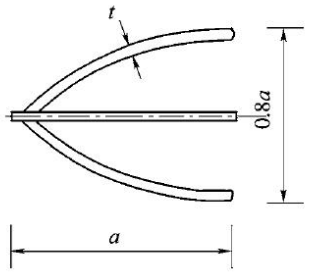



**Figure 2.14.2.2(1)**

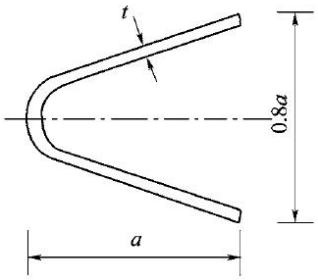



**Figure 2.14.2.2(2)**

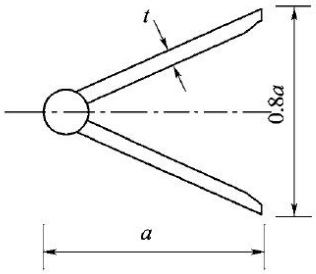



**Figure 2.14.2.2(3)**

2.14.2.3 The scantlings of cast propeller posts (as shown in Figure 2.14.2.3) are not to be less than those obtained from the following formulae:

Length of stern frame: $a = 41\sqrt{L}$ mm

Thickness of stern frame: $t_1 = 3\sqrt{L}$ mm

$t_2 = 4\sqrt{L}$ mm

Radius of fillet: $R = 4.9\sqrt{L}$ mm

where: $L$ — length of ship, in m.

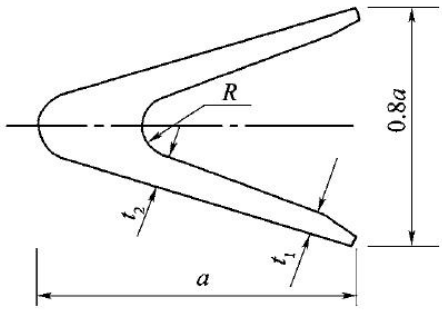



**Figure 2.14.2.3**

2.14.2.4 Fabricated or cast propeller posts are to be strengthened by horizontal brackets at positions depending upon the hull framing and the structural arrangements of propeller posts, but the spacing of the webs is not to exceed 650 mm. Cast steel stern frames are to be easy for manufacture, and all fillets are to have adequate radius; where the radius of curvature is large, a vertical web is to be fitted.

2.14.2.5 The section modulus $W_z$ of sole pieces (see Figure 2.14.2.5) about the vertical neutral axis ($z$-axis) at any considered section, is not to be less than that obtained from the following formula:

$$W_z = \frac{K}{80} Px \quad \text{cm}^3$$

where: $P$ — supporting force exerting by the sole piece on rudder blade, in N, to be calculated according to the relevant provisions of Section 1, Chapter 3 of this PART;

$K$ — material factor according to 1.3.1.7 of this PART for fabricated sole pieces; material factor according to 3.1.1.3 of this PART for cast sole pieces;

$x$ — distance between the axis of rudder stock and the section under consideration, in m, to be taken not less than $0.5l_s$, $l_s$ being the maximum distance, in m, (see Figure 2.14.2.5).

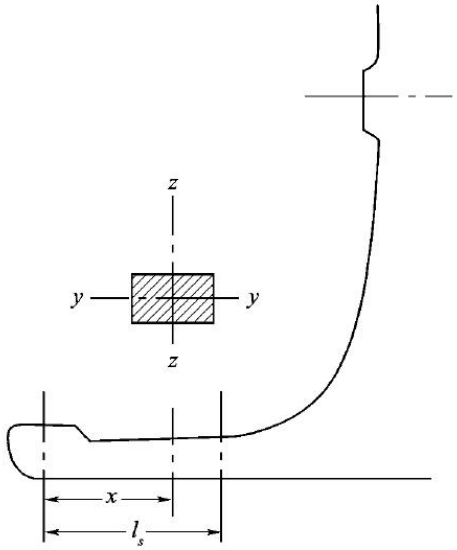



**Figure 2.14.2.5**

2.14.2.6 The section modulus $W_y$ of sole pieces about the horizontal neutral axis ($y$-axis) at any considered section is not to be less than that obtained from the following formula:

$$W_y = 0.5W_z \quad \text{cm}^3$$

where: $W_z$ — section modulus, in cm³, to be calculated according to 2.14.2.5 of this Section.

2.14.2.7 The sectional area $A_s$ at any section of the sole piece is not to be less than that obtained from the following formula:

$$A_s = \frac{K}{48}P \quad \text{mm}^2$$

where: $P$, $K$ — see 2.14.2.5 of this Section.

2.14.2.8 Within the length $l_s$, the equivalent stress $\sigma_e$ of any section of sole pieces is to be determined from following formula:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \le 115/K \quad \text{N/mm}^2$$

where: $\sigma = \dfrac{Px}{W_z}$, in N/mm², where: $P$, $x$ — see 2.14.2.5 of this Section, $W_z$ being the section modulus of the considered section about $z$-axis, in cm³;

$\tau = \dfrac{P}{A_s}$, in N/mm², where: $P$ — see 2.14.2.5 of this Section, $A_s$ being the sectional area of the section under consideration, in mm²;

$K$ — see 2.14.2.5 of this Section.

2.14.2.9 In fabricated sole pieces, transverse webs are to be fitted and spaced not more than 760 mm apart. Where the breadth of the fabricated sole pieces exceeds 900 mm, a centreline vertical web is to be fitted.

2.14.2.10 The sole piece is to extend forward from the fore end of the propeller boss for at least 3 frame spaces and to be efficiently connected to the plate keel. The sectional area of the extended portion may be reduced gradually to the area required for effective connection with the plate keel.

2.14.2.11 The stern tube shaft is to be efficiently connected to the floor or bulkhead, and the thickness of the floor is to be increased by 3 mm.

2.14.2.12 The finished thickness $t$ of the propeller boss in way of the passage of the stern tube shaft or propeller shaft is not to be less than that obtained from the following formula:

$$t = 0.1d_s + 60 \quad \text{mm, but not greater than } 0.3d_s$$

where: $d_s$ — diameter of stern tube shaft or propeller shaft, in mm.

### 2.14.3 Propeller posts of twin screw ships

2.14.3.1 The dimensions of propeller posts which are built integral with the hull of twin screw ships (see Figures 2.14.3.1(1), (2)) are not to be less than as given below:

| | | |
|---|---|---|
| Breadth of section: | $b = 33\sqrt{L}$ | mm |
| Thickness of section: | $t_1 = 3.3\sqrt{L}$ | mm |
| | $t_2 = 3.7\sqrt{L}$ | mm |
| | $t_3 = 4.5\sqrt{L}$ | mm |
| Radius of fillet: | $R = 4.4\sqrt{L}$ | mm |

where: $L$ — length of ship, in m.

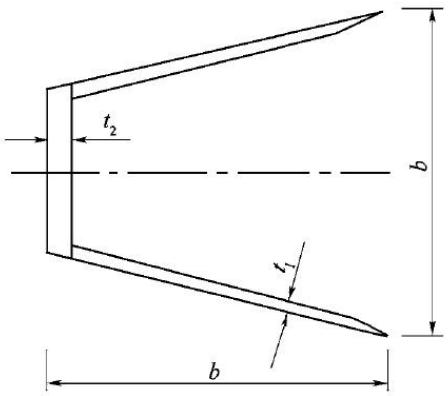



**Figure 2.14.3.1(1)**

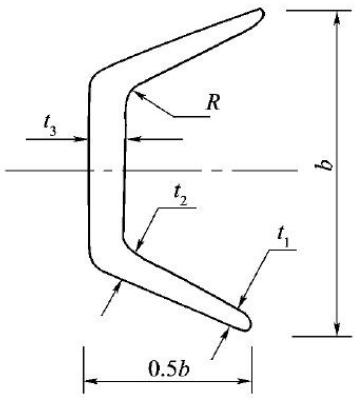



**Figure 2.14.3.1(2)**

### 2.14.4 Propeller clearances

2.14.4.1 It is recommended that the minimum clearances (see Figure 2.14.4.1) between the propeller and the stern frame or between the propeller and the rudder be not less than the following:

$$a = 0.12D \quad \text{m}$$
$$b = 0.20D \quad \text{m}$$
$$c = 0.14D \quad \text{m}$$
$$d = 0.04D \quad \text{m}$$

where: $D$ — diameter of propeller, in m.

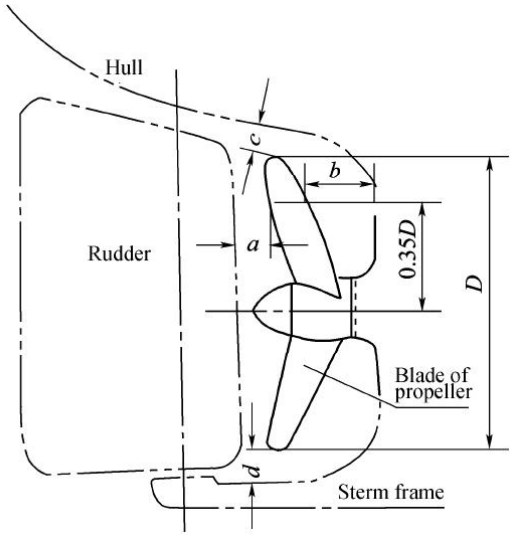



**Figure 2.14.4.1**

### 2.14.5 Bulbous bows

2.14.5.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure. The bulb is in general to be strengthened as follows:

(1) At the fore end of the bulb, the structure is to be supported by horizontal diaphragm plates spaced about 1 m apart in conjunction with the center girder;

(2) Vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing;

(3) In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or web frames spaced about 5 frame spaces apart are generally to be fitted;

(4) In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted;

(5) The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness may be the same as that required for plate stems.

### 2.14.6 Propeller shaft brackets

2.14.6.1 Propeller shaft brackets may be made of steel castings or fabricated from plates, or made of cast or forged pieces connected by welding. The connection of the arms to the bearing boss is to be made by full penetration welding.

2.14.6.2 The scantlings of each arm and shaft bossing of herringbone propeller shaft bracket are not to be less than as given below:

| | | |
|---|---|---|
| Thickness of arm: | $t = 0.45 d_s$ | mm |
| Cross sectional area of arm: | $A = 0.45\, d_s^2$ | mm² |
| Thickness of shaft bossing: | $t = 0.33 d_s$ | mm |

Length of shaft bossing: $l = 3d_s$ mm

where: $d_s$ — diameter of stern tube shaft or propeller shaft at the location of shaft bracket, in mm.

2.14.6.3 The hull framing in way of the bracket palm is to be strengthened and the shell plating in way is to be increased in thickness as required in 2.3.6.1 of this Chapter. Bracket arms are to be carried through the shell plating and efficiently attached to floors, girders and shell plating.

# Section 15 STRENGTHENING AT ENDS OF SHIP

### 2.15.1 Fore peak strengthening

2.15.1.1 Solid floors are to be fitted at every frame. The web depth $h$ and thickness $t$ and the face plate sectional area $A$ of the floors are not to be less than those obtained from the following formulae:

$h = 85D + 140$ mm, but need not be greater than 1500 mm

$t =（0.03L+6）\sqrt{K}$ mm

$A = 0.85BK$ cm²

where: $B$ — breadth of ship, in m;

$D$ — moulded depth of ship, in m;

$L$ — length of ship, in m, to be taken as not greater than 200 m;

$K$ — material factor.

2.15.1.2 Centreline keelson is to be fitted at the longitudinal centreline section. The web depth and thickness and the face plate sectional area are to be as those required in 2.15.1.1 of this Section for solid floors.

2.15.1.3 For the extremely narrow bottom, the centreline keelson not extended to the bottom may be accepted, but the depth of the keelson is to be approximately equal to 1/3 of the floor depth. Or alternatively, the centreline keelson may be entirely omitted provided that the web of floors is fitted with horizontal stiffeners and that a perforated flat, instead of a face plate, is fitted at the top edge of the web.

2.15.1.4 In the case as mentioned in 2.15.1.3 of this Section, a centreline keelson gradually tapered off over several frame spaces is to be fitted forward of the collision bulkhead as the continuation of the centreline girder or centreline keelson abaft the collision bulkhead.

2.15.1.5 Where the side shell is framed transversely, panting beams spaced not more than 2 m apart vertically are to be fitted at alternate frames, from the top of floors up to the lowest deck, and at least to 1 m above the full-load waterline. The cross-sectional area $A$ and minimum section moment of inertia $I$ of the panting beams are not to be less than:

$A = (0.27L + 8)K$ cm²

$I = cehl^2$ cm⁴

where: $L$ — length of ship, in m, to be taken as not greater than 250 m;

$c$ — horizontal spacing of panting beams, in m;

$e$ — vertical spacing of panting beams, in m;

$h_i$ — vertical distance, in m, measured from the beam to 3 m above the minimum bow height required by load line, and not to be less than that to upper deck;

$l$ — span of panting beam, in m;

$K$ — material factor.

2.15.1.6 Where a fore peak space is used as a tank and the breadth of the tank at its widest point exceeds 0.5$B$ ($B$ being the breadth of ship), efficient supporting members or wash bulkheads are to be fitted to support the panting beams. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter.

2.15.1.7 Where the length of the fore peak space exceeds 10 m, additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided. Transverse wash bulkheads are to comply with the provisions in 2.13.10.2 of this Chapter while web frames are to comply with the provisions in 2.7.2.8 of this Chapter.

2.15.1.8 Where the side shell is framed transversely, side stringers with flange or face plate are to be fitted at each panting beam, and are to have a web depth $h$ and thickness $t$ not less than:

$$h = 5.6L + 166 \quad \text{mm} \quad \text{for } L < 90\text{m}$$
$$h = 3.0L + 400 \quad \text{mm} \quad \text{for } L \geq 90\text{m}$$
$$t = 0.023L + 6 \quad \text{mm}$$

where: $L$ — length of ship, in m, to be taken as not greater than 250 m.

2.15.1.9 Brackets are to be fitted at the lower edge of connections between side stringers and frames, the thickness of brackets is not to be less than that of the side stringer web and the brackets are to be extended to the flange or face plate of side stringers. Where panting beams are fitted, the arm length of brackets along the frames is not to be less than 75% the web depth of side stringers, and where no panting beams are fitted, the arm length is not to be less than 50% the web depth of side stringers. The webs of side stringers are to be welded to the frames.

2.15.1.10 Where the side shell is framed transversely and if perforated flats are fitted in lieu of the panting beams in association with stringers, the flats are to be spaced not more than 2.5 m apart and are to be fitted vertically from the top of floors to the lowest deck above the full-load waterline, but not below 1.0 m above the full-load waterline.

2.15.1.11 Where the side shell is framed transversely, the perforated flats are to comply with the following requirements:

(1) The area of perforations in each flat is not to be less than 10% of the total area of the flat.

(2) The plate thickness $t$ of the perforated flat is not to be less than that obtained from the following formula:

$$t = 0.023L + 5 \quad \text{mm}$$

where: $L$ — length of ship, in m.

(3) Where the perforated flat is framed transversely, one beam is at least to be fitted at alternate frames below the perforated flat, and their sectional area $A$ without attached plating is not to be less than that obtained from the following formula:

$$A = (0.13L + 4)CK \quad \text{cm}^2$$

where: $L$ — length of ship, in m.

$C$ — coefficient, $C$ =1 when beams are fitted at alternate frames; $C$ =0.5 when beams are fitted at every frame;

$K$ — material factor.

Where the perforated flat is framed longitudinally, an appropriate number of transverses are to be fitted below the perforated flat, and the size of transverses and longitudinals is to be specially considered.

(4) Scantlings of the brackets connecting the beams of the perforated flat to the frames are to comply with the requirements in 1.2.6 of this PART.

2.15.1.12 Where the side shell is framed longitudinally and the depth of the forepeak exceeds 10 m, one or more perforated flats are to be provided at suitable positions, or one or more panting beams as required in 2.15.1.5 of this Section are to be provided in way of each web frame.

2.15.1.13 Where the side shell is framed longitudinally, an adequate number of transverses are to be arranged at the top of the forepeak and at perforated flats (if fitted). The brackets connecting transverses to web frames are to be in accordance with the requirements of 1.2.7 of this PART.

2.15.1.14 Where the side shell is framed longitudinally, the perforated flats are to comply with the requirements of 2.15.1.11(1) to (3) and brackets are to be fitted at the connection between the beams of perforated flats and the side plating and extended to the adjacent side longitudinals.

2.15.1.15 Brackets are to be fitted in way of fore edge of the connection between web frames and side longitudinals. The thickness of brackets is not to be less than the web thickness of web frames and the brackets are to be extended to the face plate of web frames. Where panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 75% of the web depth of web frames and where no panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 50% of the web depth of web frames.

2.15.1.16 Longitudinally framed bottom structure is to be specially considered.

### 2.15.2 Strengthening at sides abaft the fore peak tank

2.15.2.1 Where the side shell is framed transversely, side framing within the region from 0.15$L$ from F.P. to the collision bulkhead is to be strengthened as follows:

(1) Where the span of main frames does not exceed 9 m, intercostal side stringers are to be fitted in line with the side stringers or perforated flats in the fore peak tank.

(2) Where the span of main frames does not exceed 9 m and if intercostal side stringers are omitted, the side shell plating in the region concerned is to be increased in thickness by the percentages given below:

where $L \leq 150$ m, by 15% of the thickness as required in this Chapter;

where $L \geq 200$ m, by 5% of the thickness as required in this Chapter.

For intermediate values of $L$, the percentage increase is to be obtained by interpolation.

(3) Where the span of main frames exceeds 9 m, intercostal side stringers are to be fitted and to extend abaft to 0.2$L$ from the F.P. in line with the side stringers or perforated flats in the fore peak tank.

(4) Where the span of frames exceeds 2.6 m in the lower 'tween deck or 3 m in the upper 'tween deck, intercostal side stringers are to be fitted. Where the shell plating is increased according to the requirements in (2) above, the side stringers may be omitted.

2.15.2.2 The web depth of intercostal side stringers as required in 2.15.2.1 of this Section may be the same as that of frames. However, the web plate of such stringers is to be gradually increased in depth for at least two frame spaces to the collision bulkhead so that the depth at the bulkhead is the same as that of the side stringers in the fore peak tank. Where perforated flats are fitted in the fore peak tank, the depth of the web of side stringers is to be calculated according to 2.15.1.8 of this Section. The web thickness $t$ and the face plate sectional area $A$ of the intercostal side stringers are not to be less than those obtained from the following formulae:

$$t = 0.023L + 6 \quad \text{mm, but need not be greater than 12 mm}$$

$$A = 0.14L + 1 \quad \text{cm}^2\text{, but not to be less than 7 cm}^2$$

where: $L$ — length of ship, in m.

### 2.15.3 Strengthening of bottom forward

2.15.3.1 Where the length $L$ of the ship is equal to 65 m or over and the draught forward in navigation is less than $0.04L$, the flat portion of bottom from F.P. is to be strengthened. The transverse extent of strengthening is not to be less than $0.014B$ ($B$ being the breadth of the ship) above the base line, but need not be greater than 0.28 m, and the length $X$ from the end line of the longitudinal extent of strengthening to F.P. is not to be less than that obtained from the following formula:

$$X = \left(0.65 - \frac{C_b}{2}\right)L \quad \text{m}$$

where: $L$ — length of ship, in m;

$C_b$ — block coefficient, to be taken as 0.7 for $C_b < 0.7$, and 0.8 for $C_b > 0.8$.

For oil tankers provided with dedicated ballast water tanks,, the minimum forward draught is to be determined according to the conditions in which only segregated ballast tanks are used.

2.15.3.2 Where strengthening is required, double bottom framed transversely is to be strengthened as follows:

(1) Plate floors are to be fitted at every frame space.

(2) Side girders are in general to be fitted not more than three frame spaces apart, and half-depth flanged side girders are to be fitted midway between the side girders. The side girders and half-depth side girders are to be extended as far forward as practicable.

2.15.3.3 Where strengthening is required, double bottom framed longitudinally is to be strengthened as follows:

(1) Plate floors are to be fitted at alternate frames, and spaced not more than 2.5 m apart.

(2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, $l$ in the formula is not to be less than 1.85 m.

(3) Side girders are in general to be fitted not more than three times the spacing of longitudinals apart and are to be extended as far forward as practicable.

2.15.3.4 Where strengthening is required, single bottom framed transversely is to be strengthened as follows:

(1) In addition to complying with the requirements of 2.15.1.1 of this Section, floors are to be increased gradually in depth towards the fore end as far as practicable, and the floor web is to be adequately increased in thickness so as to ensure its stability. The sectional area of the face plate of floors is to be increased by 50% over the value required in 2.15.1.1 of this Section and flanges are not to be substituted for face plates of floors.

(2) Side keelsons are to be fitted not more than three frame spaces apart, and half-depth side keelsons or other equivalent bottom longitudinal stiffening members are to be fitted midway between the side keelsons and extended as far forward as practicable.

2.15.3.5 In the Where strengthening is required, the forward bottom plating is to be strengthened as follows:

(1) The thickness $t$ of the forward bottom plating is not to be less than that obtained from the following formula:

$$t = CC_1\left(1.8 - 26\frac{d_1}{L}\right)\sqrt{\frac{seK}{s_b}} \quad \text{mm}$$

where: $L$ — length of ship, in m;

$d_1$ — minimum draught forward in navigation, in m;

$s$ — spacing of frames, in m;

$s_b$ — standard spacing of frames, in m;

$e$ — correction coefficient of longitudinal position, see Table 2.15.3.5;

$C$ — coefficient: $C = 7.3 + 0.081L$ for $65 \text{ m} \le L \le 145$ m;

$C = 19.0$ for $145 < L \le 200$ m;

$C = 23.6 - 0.023L$ for $200 < L \le 300$ m;

$C = 16.7$ for $L > 300$ m;

$C_1 = 1.2 - \frac{s}{2l}$, where $l$ is the spacing of primary members, $C_1$ is to be taken as 1 for $C_1 > 1$;

$K$ — material factor.

**Correction Coefficient *e*** **Table 2.15.3.5**

| Position | $e$ |
|---|---|
| Between $X - 0.125L$ to $X$ from F.P. | $\frac{2f-1}{0.05 - C_b}$ |
| Between F.P. and $X - 0.2L$ from F.P. | $0.5 + \frac{f}{0.9 - C_b}$ |
| Others | 1 |

where: $C_b$ — see 2.15.3.1 of this Section;

$f$ — the ratio of the distance of $x$, in m, from F.P. and length of ship $L$, in m, i.e. $f = X/L$;

$X$ — see 2.15.3.1 of this Section.

(2) The strengthened forward bottom plating is to be gradually tapered to adjacent shell plating.

2.15.3.6 The forward bottom strengthening is to be verified by direct calculation assessment as specified in Appendix 4 of this Chapter if any of the following conditions applies:

(1) where the minimum forward draught of a ship is less than $0.01L$;

(2) where the arrangements of primary members do not comply with the relevant requirements of 2.15.3 of this Section.

2.15.3.7 In the strengthening region for single bottom framed longitudinally:

(1) Plate floors complying with the provisions of 2.15.3.4 (1) are to be fitted at alternate frames.

(2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, $l$ in the formula is not to be less than 1.85 m; side keelsons are to be fitted not more than three times the spacing of longitudinals apart and extended as far forward as practicable.

### 2.15.4 Aft peak strengthening

2.15.4.1 Plate floors are to be fitted at every frame space, the thickness of which is to be 1.5 mm thicker than that in the fore peak as required in this Section. In single screw ships, floors are to be carried well above the stern tube. In way of propeller posts, propeller shaft brackets and rudder

horns, the floors are generally to be carried to the top of the space and are to be increased in thickness.

2.15.4.2 Where the side shell is framed transversely, panting beams and side stringers spaced vertically not more than 2.5 m apart are to be fitted above the floors, or alternatively, perforated flats complying with the requirements of 2.15.1.11 of this Section are to be provided. The panting beams and side stringers as well as the connection of these members to frames are to comply with the requirements for the fore peak.

2.15.4.3 Where the side shell is framed longitudinally, suitable transverses are to be arranged at the top of the tank and the brackets connecting the transverses to web frames are to comply with the requirements of 1.2.7 of this PART.

2.15.4.4 A centreline wash bulkhead is in general to be arranged in tanks, the upper part of the after peak space and counter or cruiser stern. Where the overhang is very large, additional longitudinal wash bulkheads may be required port and starboard. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter, and stiffeners are to be fitted at every frame space.

### 2.15.5 Side strengthening above the aft peak

2.15.5.1 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed and the height of such spaces is more than 3 m, intercostal panting stringers are to be provided, of which the web depth is to be the same as that of frames. The web thickness and the sectional area of face plates of these intercostal stringers are to comply with the requirements of 2.15.2.2 of this Section. Where no intercostal side stringer is fitted, the thickness of shell plating within the region is to be increased in accordance with the requirements of 2.15.2.1(2) of this Section.

2.15.5.2 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed, web frames are to be fitted not more than 4 frame spaces apart. The section modulus $W$ of web frames is not to be less than that obtained from the following formula:

$$W = 3.5Sdh\sqrt{D}\,K \quad \text{cm}^3$$

where: $S$ — spacing of web frames, in m;

$d$ — draught of ship, in m;

$h$ — height of 'tween deck spaces, in m;

$D$ — moulded depth, in m;

$K$ — material factor.

2.15.5.3 Where the side shell of 'tween deck spaces above the after peak tank is framed longitudinally, web frames supporting longitudinals are to be fitted. The spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less; and not greater than 3.5 m for ships of 300 m or over in length; the intermediate values are to be obtained by interpolation. The section modulus $W$ of the frames is not to be less than that obtained from the following formula:

$$W = 4.4Sdh\sqrt{D}\,K \quad \text{cm}^3$$

where: $S$, $d$, $h$, $D$ and $K$ — the same as those in 2.15.5.2 of this section.

### 2.15.6 Structural strengthening for bow flare

2.15.6.1 For container ships, ro-ro ships, passenger ships, car carriers and the ships with the similar bow flare, the side structural strengthening at bow is to meet the requirements of Section 8, Chapter 7 of this PART.

# Section 16 ENGINE SEATINGS AND SHAFT TUNNELS

### 2.16.1 Main engine seatings

2.16.1.1 The main engine seating is to be of ample strength and rigidity. It is generally to consist of two longitudinal girders with transverse diaphragms and transverse brackets fitted at every frame space. Transverse diaphragms are to be fitted between longitudinal girders and are to extend to the face plate of girders as far as practicable. Transverse brackets, the width of which is generally not to be less than their depth, are to be fitted at the outside of the longitudinal girders and welded to the face plate of the girders.

2.16.1.2 The longitudinal girders of the seating are to be in line with the bottom side girders. If it is impracticable to do so, partial girders of the same thickness as the bottom side girders are to be fitted under the longitudinal girders.

In particular cases, the partial girder may be in the form of a half-depth girder welded to the inner bottom plating and floors only.

2.16.1.3 Scantlings of structural members of main engine seatings

(1) For large low-speed diesel engines having a power of more than 1,470 kW, the horizontal face plate thickness $t$ and the web thickness $t_1$ of longitudinal girders, and the thickness $t_2$ of transverse diaphragms and transverse brackets are not to be less than the values given below:

$$t = 1.44\ \sqrt[3]{p} + 10s \quad \text{mm}$$

$$t_1 = 0.65t\ (1+\frac{h-1}{10}) \quad \text{mm for } L \geq 90 \text{ m}$$

$$t_1 = 0.70t \quad \text{mm for } L < 90 \text{ m}$$

$$t_2 = 0.77t_1 \quad \text{mm for } L \geq 90 \text{ m}$$

$$t_2 = 0.80\ t_1 \quad \text{mm for } L < 90 \text{ m}$$

where: $P$ — main engine power, in kW;

$s$ — spacing of frames, in m;

$h$ — web depth of longitudinal girders, in m.

(2) For main engines having a power of 1,470 kW or less, the web thickness of longitudinal girders is to be increased by 60% above that of the bottom side girders (for double bottom) or side keelsons (for single bottom) in way of the engine room in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. In both cases, the longitudinal girders are to be provided with a continuous horizontal face plate having a thickness 40% greater than their web thickness. The longitudinal girders are to be gradually tapered off at their ends.

The thickness of the transverse diaphragms and transverse brackets is to be increased by 40% above that of the floors in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. The transverse diaphragms and transverse brackets are to be provided with a face plate or flange.

(3) The scantlings of main engine seatings may be suitably reduced in the case of high-powered turbines, propulsion motors or medium/high speed diesel engines.

2.16.1.4 The horizontal face plates of longitudinal girders are to be stiffened in way of holding-down bolts by a suitable number of vertical brackets, and the depth of the brackets is to be twice their breadth.

2.16.1.5 Where the main engine seating or the thrust seating is directly bolted to the inner bottom, the thickness $t_3$ of the inner bottom plating in way is not to be less than that required as follows:

(1) for large low-speed diesel engines having a power of more than 1,470 kW, $t_3 = t$, $t$ as defined in 2.16.1.3(1) of this Section;

(2) for main engines having a power of 1,470 kW or less, $t_3$ is to be equal to twice the thickness of the inner bottom plating in the region, but is not to be less than 20 mm;

(3) for high-powered turbines, etc., $t_3$ will be specially considered.

The double bottom tanks within the above regions are not to be used for carrying oil fuel or water. Partial or half-depth girders are to be fitted close to holding-down bolts. The longitudinal division bulkheads and side girders in the adjacent oil or water tanks may be regarded as the partial girders at holding-down bolts.

### 2.16.2 Shaft tunnels

2.16.2.1 Shaft tunnels are to be of watertight construction.

2.16.2.2 The thickness of tunnel plating is to comply with the requirements of 2.12.3.1 of this Chapter for watertight bulkheads. If the top plating is curved, the thickness may be reduced by 10% in dry cargo holds. If the top plating is flat, it is not to be less than 1.1 times the thickness required for the watertight bulkheads.

The thickness of top plating of the tunnel under hatchways is to be increased by at least 2 mm, unless covered with wood ceiling as required in 3.3.1.5 of this PART.

2.16.2.3 Stiffeners of shaft tunnels are to be in line with the frames wherever possible, and their section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 6shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — the vertical distance, in m, measured from the mid-point of the vertical part of the stiffener to bulkhead deck;

$l$ — the length of the vertical part of the stiffener, in m;

$K$ — material factor.

Where the tunnel top is flat, the scantlings of the top beams are not to be less than those required for the beams in way of the steps in watertight bulkheads (see 2.12.8 of this Chapter).

The lower end of the vertical part of stiffeners is to be welded to the inner bottom.

2.16.2.4 Where shaft tunnels pass through or are adjacent to deep tanks, the adjacent bulkheads and their stiffeners are to comply with the requirements of Section 13 of this Chapter for deep tanks.

2.16.2.5 The structure of the thrust and tunnel recesses is to comply with the requirements for the steps in watertight bulkheads. Where these recesses are enclosed by deep tanks, the requirements for bulkheads and stiffeners of deep tanks are to be complied with.

2.16.2.6 The shaft tunnel is to be provided with an emergency exit leading to the weather deck, and the construction of the trunk of the exit is to comply with the requirements for watertight bulkheads. The closing appliance for the exit is to be capable of being operated from both sides.

# Section 17 SUPERSTRUCTURES AND DECKHOUSES

### 2.17.1 General requirements

2.17.1.1 All ships are to be provided with forecastles or increased sheer to such a minimum bow height as to meet the requirements of the the Administration of China.2.17.1.2 Where superstructures and deckhouses are subject to loading in excess of that as specified in this Section, the scantlings of their structural members are to be appropriately increased in addition to complying with the requirements of this Section.

2.17.1.3 Where long superstructures are provided within 0.5*L* midships, the deck structure of the 1st tier is to comply with the requirements for strength decks and side shell is to comply with the requirements for shell plating.

2.17.1.4 Where long deckhouses are provided within 0.5*L* midships, the thickness of plating and the size of framing of the 1st tier is to be increased according to the contribution of these deckhouses to the longitudinal bending of hull girders.

2.17.1.5 The deckhouses on forecastle deck of offshore supply ships are to comply with the requirements of Section 5, Chapter 11 of this PART.

2.17.1.6 Definitions of tiers of superstructures/deckhouses: The lowest, or first tier, is normally that tier which is directly situated on the uppermost continuous deck to which the Rule moulded depth *D* is to be measured. The second tier is the next tier above the lowest tier and so on.

2.17.1.7 The deck plating of No.N tier of superstructure/deckhouse is the top plating of this tier of superstructure/deckhouse.

2.17.1.8 Where a freeboard corresponding to or exceeding the uncorrected tabular values of the loadline requirements can be obtained for a ship with excessive freeboard, i.e. by considering the ship to have a virtual moulded depth *D′* at least one standard superstructure height less than the Rule moulded depth *D* (see Figure 2.17.1.8), the 1st tier erection may be treated as the 2nd tier, and the 2nd tier as the 3rd tier when applying the requirements of this Section. The standard superstructure height $h_s$ is to be obtained as follows:

$$h_s = 1.05 + 0.01L_L \quad \text{m, and } 1.8 \le h_s \le 2.3$$

where: $L_L$ — load line length of ship, in m.

However, this does not apply to type ‘B’ ships with reduced freeboard.

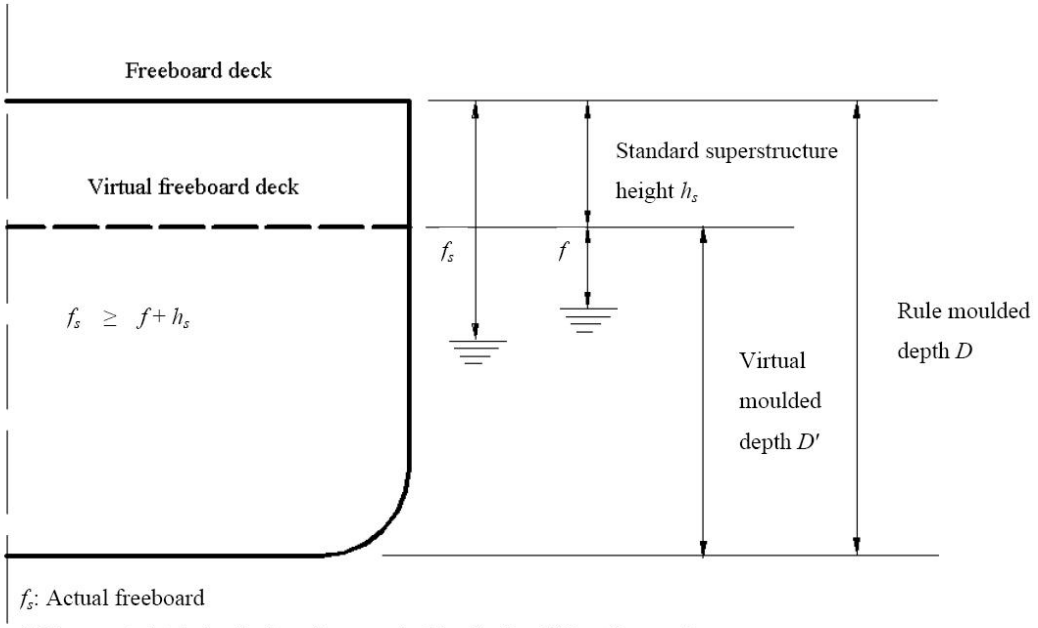



**Figure 2.17.1.8**

### 2.17.2 Design pressure head

2.17.2.1 The design pressure head $h$ for end bulkheads of exposed superstructures and boundary bulkheads (end and side bulkheads) of deckhouses is to be obtained as follows and not less than the minimum value in Table 2.17.2.1:

$$h = \alpha\delta(\beta\lambda - \gamma) \quad \text{m}$$

where: $\alpha$, $\beta$, $\lambda$ and $\delta$ — coefficients, to be determined respectively according to 2.17.2.2, 2.17.2.3, 2.17.2.4 and 2.17.2.5 of this Section;

$\gamma$ — vertical distance, in m, measured from summer load waterline to mid-span of stiffener or mid-point of panel.

**Table 2.17.2.1**

| Length of ship $L$ (m) | Design pressure head $h_{min}$ (m) | |
|---|---|---|
| | Lowest tier of unprotected fronts | Elsewhere |
| $L \leq 50$ | 3.0 | 1.5 |
| $50 < L < 250$ | $0.01L + 2.5$ | $0.005L + 1.25$ |
| $L \geq 250$ | 5.0 | 2.5 |

2.17.2.2 Coefficient $\alpha$ is to be determined as follows:

$\alpha = 0.0083L_1 + 2.0$, lowest tier of unprotected fronts

$\alpha = 0.0083L_1 + 1.0$, second tier of unprotected fronts

$\alpha = 0.0067L_1 + 0.5$, third tier of unprotected fronts and above, protected fronts and sides of all tiers

$\alpha = 0.001L_1 - 0.8\,(X/L) + 0.7$, aft ends of all tiers where aft of amidships

$\alpha = 0.001L_1 - 0.4\,(X/L) + 0.5$, aft ends of all tiers where forward of amidships

where: $L$, $L_1$ — length of ship, in m; $L_1$ need not be taken greater than 300 m;

$X$ — distance, in m, between bulkhead considered and A.P. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal

length, not exceeding 0.15$L$ each and $X$ is to be taken as the distance between A.P. and the centre of each part considered.

2.17.2.3 Coefficient $\beta$ is to be determined as follows:

$$\beta = 1.0 + \left( \frac{X/L - 0.45}{C_b + 0.2} \right)^2 \text{, for } X/L \leq 0.45$$

$$\beta = 1.0 + 1.5\left( \frac{X/L - 0.45}{C_b + 0.2} \right)^2 \text{, for } X/L > 0.45$$

where: $L$ — length of ship, in m;

$X$ — see 2.17.2.2;

$C_b$ — block coefficient, where $C_b < 0.6$, to be taken as 0.6; where $C_b > 0.8$, to be taken as 0.8; where the aft end bulkhead of the superstructure is forward of amidships, $C_b$ used in determining the value $\beta$ for the aft end bulkhead is not to be taken as less than 0.8.

2.17.2.4 Coefficient $\lambda$ is to be determined as follows:

$\lambda = \frac{L}{10} e^{-L/300} - [1 - (\frac{L}{150})^2]$ for $L < 150$ m

$\lambda = \frac{L}{10} e^{-L/300}$ for 150 m $\leq L <$ 300 m

$\lambda = 11.03$ for $L \geq 300$ m

where: $L$ — length of ship, in m.

2.17.2.5 Coefficient $\delta$ is to be determined as follows:

$$\delta = 0.7\frac{b}{B_1} + 0.3 \text{, and not less than 0.475}$$

where: $b$ — breadth of deckhouse at the position considered, in m;

$B_1$— actual maximum breadth of ship on the exposed weather deck at the position considered, in m.

For exposed parts of superstructures, machinery casings and deckhouses protecting pump room openings, $\delta$ is to be taken as 1.

### 2.17.3 End bulkheads of superstructures and boundary bulkheads of deckhouses

2.17.3.1 The thickness $t$ of end bulkhead plating of superstructures and boundary bulkhead plating of deckhouses is not to be less than:

$$t = 3s\sqrt{hK} \quad \text{mm}$$

The minimum thickness of the plate, $t_{min}$, is to comply with the following requirements:

If $L_1 \geq$65 m: $t = (0.01L_1 + 5.0)\sqrt{K}$ mm, for lowest tier

$t = (0.01L_1 + 4.0)\sqrt{K}$ mm, for upper tiers, and not less than 5 mm

If $L_1 <$65 m: $t_{min}$ =5.0 mm, for the lowest unprotected front

$t_{min}$ =4.0 mm for all other cases

where: $s$ — spacing of stiffeners, in m;

$h$ — design pressure head, in m, to be calculated according to 2.17.2 of this Section;

$L_1$ — length of ship, in m, $L_1$ need not be taken greater than 300 m;

$K$ — material factor.

2.17.3.2 The section modulus $W$ of end bulkhead stiffeners of superstructures and boundary bulkhead stiffeners of deckhouses is not to be less than:

$$W=3.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m; to be taken as height of deckhouse, but not less than 2.0 m in any case;

$h$ — calculated pressure head, in m, to be obtained according to 2.17.2 of this Section;

$K$ — material factor.

Except as required in 2.17.3.3 and 2.17.3.4 of this Section, the end of stiffeners of enclosures of the deckhouse may not be fitted with brackets, provided that the webs of stiffeners are welded to the deck effectively. The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below, taking account of spacing and span.

2.17.3.3 The ends of following stiffeners are to be bracketed or connected by equivalent arrangements. The scantlings of brackets are to be determined according to the relevant provisions of 1.2.6 of this PART:

(1) Front stiffeners of the lowest tier;

(2) Front stiffeners of upper tiers in ships over 150 m in length;

(3) Side stiffeners of single tier deckhouse;

(4) Aft stiffeners of the lowest aft deckhouse;

(5) Side stiffeners of upper deckhouses when the length of ship is greater than 150 m, side stiffeners of the lowest deckhouse if two or more tiers of deckhouses are fitted; where such stiffeners are not bracketed but directly welded to the deck, their section modulus is to be increased by 20%.

2.17.3.4 For exposed machinery and pump-room casings, the front stiffeners on amidships casing and all stiffeners on aft end casings which are situated on the deck to which the moulded depth $D$ is measured are to be bracketed at top and bottom. Where such stiffeners are not bracketed but directly welded to the deck, their section modulus is to be increased by 20% above that required for the stiffeners of deckhouses in the corresponding positions. All other stiffeners on exposed machinery and pump-room casings are to be welded to the decks at top and bottom.

### 2.17.4 Sides of superstructures

2.17.4.1 The side framing of superstructures is to comply with the following requirements:

(1) Where the side shell is framed transversely, the relevant requirements of Section 7 of this Chapter are to be complied with.

(2) Where the sides of superstructures are framed longitudinally and located within the range of 0.3$L$ from A.P. forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 6.5sl^2(0.6+0.167D_1)K \quad \text{cm}^3$$

where: $s$— spacing of longitudinals, in m;

$l$ — span of longitudinal, in m, not less than 1.5 m;

$D_1 = d + H_b$, in m, not greater than 20 m,

where: $H_b$— the minimum bow height as required by load line assignment, in m;

$d$ — draught, in m;

$K$— material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 8.8Sl^2(0.6 + 0.167D_1)K \qquad \text{cm}^3$$

where: $D_1$, $K$ — the same as those in the above formula;

$S$ — spacing of web frames, in m;

$l$ — span of web frames, in m.

(3) Where the sides of superstructures are framed longitudinally and located beyond the range of 0.3$L$ from A.P forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 7.5sl^2(0.6 + 0.167D_2)K \quad \text{cm}^3$$

where: $s$— spacing of longitudinals, in m;

$l$— span of longitudinal, in m, not less than 1.5 m;

$D_2 = d + H_b$, in m;

where: $H_b$— the minimum bow height as required by load line assignment, in m;

$d$ — draught, in m;

$K$— material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 10Sl^2(0.6 + 0.167D_2)K \qquad \text{cm}^3$$

where: $D_2$, $K$ — the same as those in the above formula;

$S$ — spacing of web frames, in m;

$l$ — span of web frames, in m.

Where the superstructure is located within the range of 0.4$L$ amidships and contributes to the longitudinal strength, the relevant requirements of 2.2.7, Section 2 of this Chapter are also to be complied with.

2.17.4.2 The side plating of superstructures is to comply with the following requirements:

(1) The thickness $t$ of side plating of forecastles is not to be less than:

$$t = (0.028L + 5.5)\sqrt{\frac{sK}{s_b}} \qquad \text{mm}$$

where: $L$ — length of ship, in m;

$s$ — spacing of frames or longitudinals, in m, to be taken as not less than $s_b$;

$s_b$ — standard spacing of frames or longitudinals, in m;

$K$ — material factor.

(2) The thickness $t$ of side plating of bridge and poop is not to be less than:

$$t = (0.025L + 5)\sqrt{\frac{sK}{s_b}} \qquad \text{mm}$$

where: $L$ — length of ship, in m;

$s$ — spacing of frames or longitudinals, in m, to be taken as not less than $s_b$;

$s_b$ — standard spacing of frames or longitudinals, in m;

$K$ — material factor.

### 2.17.5 Decks

2.17.5.1 The deck framing of superstructures is to comply with the relevant requirements of Section 8 of this Chapter. The deck framing of the forecastle is also to comply with the following requirements:

(1) Within the region forward of 0.075$L$ from F.P., the spacing of deck girders supporting the beams is generally not to be more than 3.5 m, and that of the transverses supporting the deck longitudinals is generally not to be more than 2.5 m;

(2) The web depth of deck girders and transverses is not to be less than twice the depth of cutouts for the passage of beams or longitudinals being supported.

2.17.5.2 The section modulus $W$ of the deck longitudinals or beams of deckhouses is not to be less than:

$$W = 5shl^2K \quad \text{cm}^3, \text{ and not less than } 25s$$

where: $s$ — spacing of deck longitudinals or beams, in m;

$l$ — span of deck longitudinals or beams, in m;

$h$ — design pressure head, in m, to be determined as follows:

0.9 m, for those on first tier deck;

0.6 m, for those on second tier deck;

0.45 m, for those on third tier deck and above;

$K$ — material factor.

2.17.5.3 The scantlings of deck girders and transverses of deckhouses are to be calculated in accordance with the relevant requirements of Section 8 of this Chapter, but the design pressure head is to be as specified in 2.17.5.2 of this Section. The web thickness of girders of deckhouses is not to be less than 1% of their depth plus 2 mm, but not to be less than 4 mm.

2.17.5.4 The thickness $t$ of deck plating of superstructures (except the forecastle) and deckhouses is not to be less than:

$$t = (0.02L + C)\sqrt{\frac{sK}{s_b}} - t_c \quad \text{mm, and not less than 5 mm}$$

where: $L$ — length of ship, in m; not to be taken as greater than 100 m;

$s$ — spacing of deck longitudinals or beams, in m, to be taken as not less than $s_b$;

$s_b$ — standard spacing of deck longitudinals or beams, in m;

$C$ — coefficient, to be taken as follows:

5.5, for the first tier deck;

5.0, for the second tier deck;

4.5, for the third tier deck and above;

$t_c$ — $t_c$ = 1 for decks of dry spaces within superstructures or deckhouses; $t_c$ = 0 in other cases;

$K$ — material factor.

2.17.5.5 The thickness $t$ of forecastle deck plating is not to be less than:

$$t = (0.02L + 6)\sqrt{\frac{sK}{s_b}} \quad \text{mm}$$

where: $L$ — length of ship, in m;

$s$ — spacing of deck longitudinals or beams, in m, to be taken as not less than $s_b$;

$s_b$ — standard spacing of deck longitudinals or beams, in m;

$K$ — material factor.

### 2.17.6 Local strengthening of superstructures

2.17.6.1 Web frames or partial bulkheads spaced about 9 m apart are to be fitted within the poop or bridge that have large deckhouses or other erections above, to support side and end bulkheads of the deckhouses.

Appropriate strength members are also to be fitted in other areas under high loading.

2.17.6.2 The web frames or partial bulkheads within superstructures are to be arranged, where practicable, in line with the watertight bulkheads or other strength members below.

2.17.6.3 Pillars, diaphragms, bulkheads or other strength members are to be arranged under the ends of superstructures for support.

2.17.6.4 To reduce stress concentration in main hull structure in way of ends of superstructures which are flush with ship's side, the side plating of the superstructures is to extend beyond their ends and the height of the side plating is to be gradually reduced to that of the sheer strake in a smooth transition (free edges of extension plating generally in an oval shape with horizontal axis, see Figure 2.17.6.4). This plating is to be supported by stiffened brackets and to be efficiently stiffened at the upper edge by a face plate having the same thickness as the extension plating and a breadth not less than 10 times its thickness. The extension plating is to comply with the following requirements:

(1) For end bulkheads of superstructures situated within 0.5$L$ amidships, the length of the extension plating is not to be less than 1.5 times that of the superstructure and its thickness is to be increased by 25%;

(2) For end bulkheads of superstructures situated within 0.2$L$ from the ship's ends, the length of the extension plating is not to be less than the height of the superstructure and its thickness need not be increased;

(3) For end bulkheads of superstructures situated between 0.2$L$ and 0.25$L$ from the ship's ends, the increased length and thickness of the extension plating is to be obtained by interpolation.

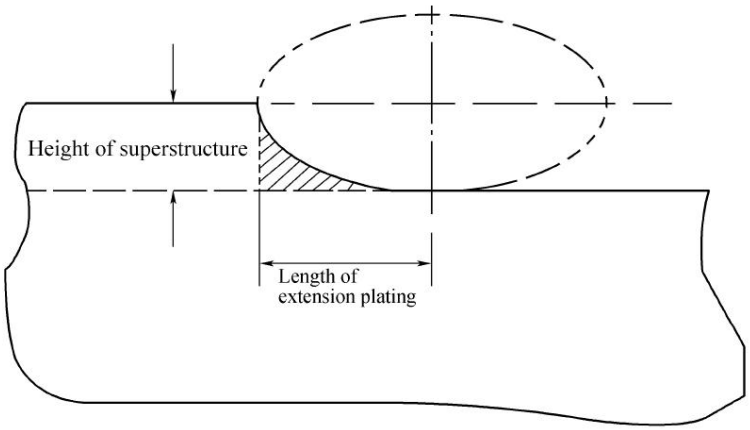



**Figure 2.17.6.4**

2.17.6.5 The thickness of the upper deck stringer plate and the sheer strake is to be increased at the ends of the superstructure from at least two frame spaces inside the superstructure to two frame spaces beyond the extension of side plating (see Figure 2.17.6.5) in accordance with the following requirements:

(1) Where the end bulkheads of the superstructure are situated within 0.5*L* amidships, the thickness of stringer plates and sheer strakes is to be increased by 20%;

(2) Where the end bulkheads of the superstructure are situated within 0.2*L* from the ship's ends, the thickness of stringer plates and sheer strakes need not be increased;

(3) Where the end bulkheads of the superstructure are situated between 0.2*L* and 0.25*L* from the ship's ends, the increased thickness of stringer plates and sheer strakes is to be obtained by interpolation.

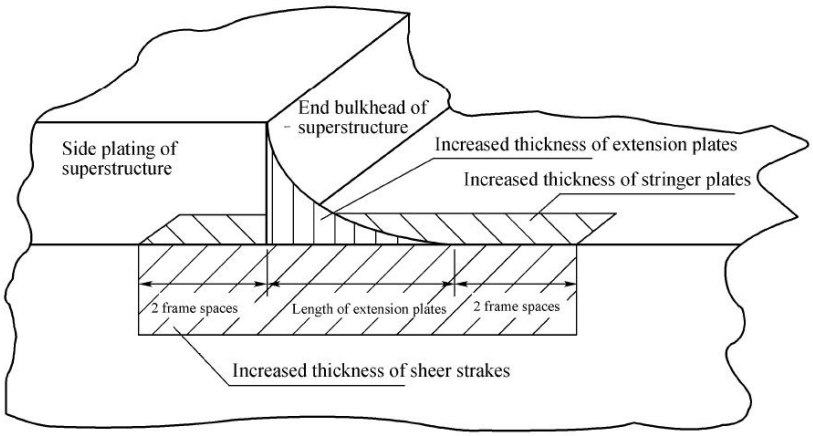



**Figure 2.17.6.5**

### 2.17.7 Local strengthening of deckhouses

2.17.7.1 Adequate support under the ends of deckhouses is to be provided in the form of pillars, diaphragms, bulkheads or other strength members. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent arrangements are generally to be fitted.

2.17.7.2 All openings cut in the sides of long deckhouses are to be adequately strengthened and have well rounded corners. Continuous coamings with adequate height are to be fitted below and above doors or similar openings. House tops are to be strengthened in way of boats and davits. Special care is to be taken to minimize the size and number of openings in the side bulkheads in the region of the ends of deckhouses within 0.5*L* amidships.

2.17.7.3 The sides and ends of the long deckhouses on the lowest tier deck are generally to be strengthened by partial bulkheads or vertical webs spaced about 9 m apart, and these stiffening members are, as far as practicable, to be arranged in line with the strengthening members within the 'tween deck space below the deckhouse.

### 2.17.8 Raised quarterdecks

2.17.8.1 The scantlings of the main frames in way of the raised quarter deck are to be determined according to the requirements of Section 7 of this Chapter. In this case the span of the frame is to be measured to the raised quarter deck.

The scantlings of the deck frames in way of the raised quarter deck are to be determined in accordance with the relevant requirements for the strength deck as specified in Section 8 of this Chapter.

The thickness of the raised quarter deck sheer strake is to be determined according to the requirements of Section 3 of this Chapter, and the thickness of deck plating is to be determined in accordance with the relevant requirements for strength deck as specified in Section 4 of this Chapter. In such cases the moulded depth is to be taken as that at the raised quarter deck.

The thickness of break bulkheads and the scantlings of stiffeners are to be determined in accordance with the requirements for end bulkheads of corresponding superstructures.

2.17.8.2 Strengthening at the break within 0.5*L* amidships

(1) For $L < 65$ m, the strength deck stringer plate and the raised quarter deck stringer plate are to extend respectively for 3 or 4 frame spaces on either side of the break bulkhead and are to be gradually tapered off;

(2) For $L \geq 65$ m, the upper and raised deck plating at the break is to overlap for 2 or 3 frame spaces, and in this case the stringer plates of both decks are to extend forward for 2 or 3 frame spaces beyond the end of overlapped plating. Vertical diaphragm plates spaced not more than 1.5 m apart in parallel with the longitudinal centreline are to be fitted between the overlapped deck plating. The thickness of the diaphragm plates is to be the same as that of the break bulkhead plating, and the diaphragms are to be efficiently stiffened and their free edges are to be flanged or provided with a face plate.

2.17.8.3 Where the break is located outside of 0.5*L* amidships, the strength deck stringer plate is to extend for 3 frame spaces beyond the break and is to be gradually tapered off.

2.17.8.4 The sheer strake is to be increased in thickness by 30% for a distance of 3 to 5 frame spaces on either side of the break bulkhead. Where a raised quarter deck is connected to a long bridge, the sheer strake of side plating within the raised quarter deck area is to be increased in thickness by 25% for a distance of at least 2 frame spaces on either side of the break, and the side plating of the bridge is to be gradually tapered in a curve line from the end of the bridge deck stringer plate into the sheer strake of side plating within raised quarter deck area over a length more than 1.5 times the height of the bridge above the raised quarter deck.

### 2.17.9 Machinery casings

2.17.9.1 Machinery space openings in the exposed deck are to be protected by strong steel casings. Machinery casings situated on the freeboard or raised quarter deck are to be enclosed in the superstructures or deckhouses so far as practicable.

2.17.9.2 Doors in machinery casings are to be of steel and rigid construction, and are to be capable of being operated from both sides.

2.17.9.3 The scantlings of boundary bulkheads of exposed casings are to be determined in accordance with the requirements for those of the deckhouses in the corresponding positions.

2.17.9.4 The scantlings of boundary bulkheads of non-exposed casings are to comply with the following requirements:

(1) The minimum thickness of boundary bulkheads of the casings is not to be less than 6.5 mm in way of cargo spaces and not to be less than 5 mm in way of accommodation spaces;

(2) The section modulus *W* of the stiffeners of boundary bulkheads of the casings is not to be less than that obtained from the following formula:

$$W = 8slK \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m;

$K$— material factor.

For ships of 65 m or over in length, the depth of stiffeners is not to be less than 60 mm.

2.17.9.5 Where casing stiffeners support the deck transverses or girders or where they are in line with pillars below, they are to be suitably strengthened.

2.17.9.6 Where the casing sides act as girders supporting decks above, the openings for doors, windows, etc., in the sides are to be effectively strengthened. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

### 2.17.10 Breakwater

2.17.10.1 The load under consideration is to be determined with the requirements for fronts of superstructures in 2.17.2 of this Section as reference.

2.17.10.2 The thickness of breakwater plating and the scantlings of breakwater stiffeners are to be determined according to 2.17.3 of this Section.

2.17.10.3 The scantlings of main members (horizontal girders and vertical webs) supporting breakwaters are to be determined by direct calculations, and the permissible stress is as follows:

$$[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 235/K \quad \text{N/mm}^2$$

where: $K$ — material factor.

## Section 18 HELICOPTER DECKS

### 2.18.1 General requirements

2.18.1.1 This Section applies to all ships fitted with areas and facilities for normal takeoff and landing of helicopters.

2.18.1.2 Helicopter decks covered by this Section mean helicopter deck structure only.

2.18.1.3 For helicopter deck connected by bolts and splice other than welding, special consideration is to be given to the requirements for structural strength.

### 2.18.2 Plans and documents

2.18.2.1 The following plans and documents are to be submitted for approval:

(1) Detailed arrangement of helicopter deck, including overall dimensions, landing area/securing area, if any;

(2) Structural plan for helicopter deck (appropriate strength calculations are submitted for information).

2.18.2.2 Loading manual is to include information on models and parameters of helicopters to be used, including maximum takeoff weight, overall length of helicopter (including rotation of rotor), size of wheel print and tracking width.

### 2.18.3 Arrangement of helicopter deck

2.18.3.1 The arrangement and construction of helicopter deck is to meet the applicable standards accepted by the flag Administration, such as the annex to IMO MSC/Circ.895—Recommendation on Helicopter Landing Areas on Ro-Ro Passenger Ships, International Chamber of Shipping (ICS)- Guide to Helicopter/Ship Operations, International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) and Offshore Helicopter Landing Areas-Guidance on Standards (CAP437).

### 2.18.4 Design conditions

2.18.4.1 The supporting structure of the helicopter platform is to be designed to the following three conditions: overall distributed loading, helicopter landing impact loading and stowed helicopter loading (if provisions are made to accommodate the helicopter secured to the deck in a predetermined position):

(1) Overall distributed loading:

① a minimum distributed loading of 2 kN/m$^2$ is to be taken over the entire helicopter deck.

(2) Helicopter landing impact loading: Combination of the following loads is to be taken into account:

① for normal landing, vertical impact loading $P_H$ = 1.5$P$ ($P$ being the maximum takeoff weight), uniformly distributed on both wheel prints when landing (landing of both wheels at the same time is generally assumed). Where no data on actual size of wheel prints are available, the size of each print may be taken as a square area of 0.30 m × 0.30 m. The structural members are to be designed according to the worst landing position with regard to forces acting on them.

Where the upper deck of a superstructure or deckhouse is used as a helicopter platform deck and the spaces below are normally manned (control room, quarters, etc.), the above vertical impact loading $P_H$ = 1.75$P$;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m$^2$, representing wet snow, ice or other environmental loading, is to be considered.

(3) Stowed helicopter loading: Combination of the following loads is to be taken into account:

① wheel loading at maximum takeoff weight, with landing area being assumed as that for helicopter landing impact loading;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m$^2$, representing wet snow, ice or other environmental loading, is to be considered;

④ in addition, where stowage of helicopters is possible, the inertial forces of helicopter and helicopter platform due to ship's motion under corresponding environmental conditions are to be considered. If no proper data are available, both the horizontal and vertical inertial forces may be taken as 0.5 times the loading corresponding to the weight of helicopter and helicopter platform structure.

2.18.4.2 For helicopters fitted with landing gear other than wheels, the landing area is to be determined according to the data provided by manufacturers.

### 2.18.5 Helicopter deck plating

2.18.5.1 The initial plate thickness of the helicopter deck may be calculated in accordance with

2.21.2.1(1) of this Chapter, with loading being the wheel impact loading required for the above design conditions.

2.18.5.2 Where the helicopter deck is the strength deck within 0.4$L$ amidships, the wheel impact loading obtained according to 2.18.5.1 of this Section is to be multiplied by a factor of 1.18. This factor is linearly reduced to 1.00 within 0.4$L$ amidships aft or forward along ship's length.

2.18.5.3 The helicopter deck plate thickness is to be based on the initial thickness calculated according to 2.18.4.1 or 2.18.4.2, and is to comply with the strength verification of the entire helicopter deck structure by direct calculation.

2.18.5.4 Hatch covers used as helicopter deck are to comply with this Section and in addition, Section 20 of this Chapter.

2.18.5.5 Where the helicopter deck forms part of a weather deck or other decks, the scantlings are not to be less than those required for decks in the same position.

### 2.18.6 Strength verification by direct calculation

2.18.6.1 Direct calculation of helicopter deck structure is to be preformed by 3-dimensional finite element structural analysis, and recognized programs and structural idealization methods are to be used.

2.18.6.2 The permissible bending stress [$\sigma$], shear stress [$\tau$] of helicopter deck plating, deck framing and their supporting structure and the permissible stress [$\sigma_{cb}$] of compressed components are as follows:

(1) The permissible bending stress [$\sigma$] is to be determined according to Table 2.18.6.2.

**Permissible Bending Stress [$\sigma$]** **Table 2.18.6.2**

| Structural member / Design condition | Deck plating | Longitudinals, transverses and other secondary deck members | Girders, web beams and other main deck members<br>Stanchions, supports and other truss supports of platform |
|---|---|---|---|
| Overall distributed loading | $0.6R_{eH}$ ③ | $0.6R_{eH}$ | $0.6R_{eH}$ ① |
| Helicopter landing impact loading | $R_{eH}$ ② | $R_{eH}$ | $0.9R_{eH}$ ① |
| Stowed helicopter loading | $R_{eH}$ | $0.9R_{eH}$ | $0.9R_{eH}$ ① |

Notes: $R_{eH}$ — yield stress of material, in N/mm$^2$; for aluminium alloy, taken as $R_{p0.2}$, see Section 3, Chapter 1 of this PART.

① Components under axial compression are to be checked to the lesser of permissible bending stress and permissible critical buckling stress.

② For helicopter landing impact loading, where the stress of helicopter deck plating is obtained according to a four-sides supported plate subjected to vertically distributed loading, the permissible stress may be taken as 1.1 $R_{eH}$.

③ For overall distributed loading, the helicopter deck plating thickness is not to be less than the minimum thickness required by 2.18.5 and the Rules.

(2) Permissible shear stress [$\tau$]: $[\tau] = [\sigma] / \sqrt{3}$ .

(3) Permissible compressive stress [$\sigma_{cb}$] is to be calculated according to 2.2.7.5(1) and 2.2.7.6 of this Chapter.

2.18.6.3 The value of the permissible bending stress for framing and girders of strength deck used as helicopter deck is to be multiplied by a reduction factor in Table 2.18.6.3.

**Reduction Factor** **Table 2.18.6.3**

| Location of helicopter deck | Reduction factor | Location of helicopter deck | Reduction factor |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Area 0.4*L* amidships | 0.7 | A.P./F.P. area | 1.0 |
| Area between A.P. and F.P. | Linear interpolation | | |

2.18.6.4 The hatch covers which are also combined to use as helicopter decks are to meet the requirements of Section 20 of this Chapter.

# Section 19 BULWARKS AND GUARDRAILS

### 2.19.1 General requirements

2.19.1.1 Guardrails or bulwarks are to be fitted around all exposed decks. The height of the bulwarks or guardrails is to be at least 1 m from the deck, provided that where this height would interfere with the normal operation of the ship, a lesser height may be approved, if the Administration is satisfied that adequate protection is provided.

2.19.1.2 The ship designed for the carriage of timber deck cargoes is to be fitted either with permanent bulwarks at least 1 m in height, specially stiffened on the upper edge and supported by strong bulwark stays attached to the deck and provided with necessary freeing ports, or with efficient rails of the same height and of specially strong construction.

### 2.19.2 Bulwarks

2.19.2.1 The plating thickness of bulwarks on freeboard decks is not to be less than 5 mm for ships having a length less than 65 m and not to be less than 6 mm for ships having a length equal to 65 m or over. The plating thickness of bulwarks elsewhere may be suitably reduced.

2.19.2.2 The top edge of bulwarks is to be stiffened by a flat bar or profile steel.

2.19.2.3 Bulwarks are to be supported by stays with flange or face plate from the deck in line with the beams or beam webs. Where the frame spacing does not exceed 620 mm, the spacing of stays is not to exceed 3 frame spaces. Where the frame spacing exceeds 620 mm or where the ship is intended for the carriage of timber deck cargoes, the spacing of stays is not to be greater than 2 frame spaces. Where the bulwarks on the forecastle deck have a great flare, stays are to be fitted at every frame.

2.19.2.4 The section modulus $W$ at the bottom of bulwark stays is not to be less than that obtained from the following formula:

$$W = (30 + 0.45L)SH^2K \quad \text{cm}^3$$

where: $S$— spacing of stays, in m;

$L$— length of ship, in m, not to be taken as greater than 100 m;

$H$— height of bulwark, in m;

$K$— material factor.

Where the flange of the stay is not welded to the deck, such a flange is not to be considered for the section modulus.

2.19.2.5 Bulwarks are to be adequately strengthened in way of mast shrouds or eyeplates for cargo gear and in way of fairleaders.

2.19.2.6 Where bulwarks are cut to form a gangway or other openings, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

2.19.2.7 Bulwarks are as far as practicable not to be welded to the sheer strake amidships so as to ensure their freedom from the longitudinal bending of the hull.

### 2.19.3 Guardrails

2.19.3.1 Guardrails fitted on superstructure and freeboard decks are to have at least three courses. The opening below the lowest course of the guardrails is not to exceed 230 mm. The other courses are to be not more than 380 mm apart. In the case of ships with rounded gunwales the guardrail supports are to be placed on the flat of the deck. In other locations, guardrails with at least two courses are to be fitted.

## Section 20 HATCHWAYS AND HATCH COVERS

### 2.20.1 General requirements

2.20.1.1 In addition to the requirements of this Section, exposed hatchways and hatch covers are to comply with the relevant requirements of the Amendments to Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.20.1.2 The structural scantlings of non-exposed hatch covers may be determined according to the relevant requirements of this Section, depending on their structural configuration and with only permissible cargo loads being taken into account.

2.20.1.3 The scantlings of steel hatch covers for deep tanks may be determined according to the relevant requirements of this Section and depending on the position of hatch covers, but in no case are to be less than those required in Section 13 of this Chapter for deep tank deck and its framing.

2.20.1.4 Where wheeled vehicles are to be stowed on hatch covers or used for cargo handling, the scantlings of hatch covers are also to comply with the requirements for vehicle deck in Section 21 of this Chapter.

2.20.1.5 The scantlings of hatch covers used as helicopter deck are also to comply with the requirements for helicopter decks in Section 18 of this Chapter.

2.20.1.6 Except as otherwise provided, the width of the attached plating of hatch cover stiffeners and girders is to be determined according to 1.2.2 of Section 2, Chapter 1 of this PART. However, the areas of stiffeners are not to be included in the area of the attached plating of girders.

2.20.1.7 For the hatch covers on the lower deck within cargo holds, the strength is to be checked according to the requirements of 2.20.3.

2.20.1.8 Height of hatch coamings

(1) at Position 1, the height is not to be less than 600 mm;

(2) at Position 2, the height is not to be less than 450 mm;

(3) for ships provided with steel weathertight hatch covers, with the consent of the flag State Administration, the height of hatch coamings may be suitably reduced provided that efficient measures have been taken and that the safety of the ship is not impaired;

(4) for hatchways on unexposed freeboard decks or exposed superstructure decks, hatchway coamings with a suitable height may be provided depending upon the position of the hatchways and the protection necessitated by such hatchways.

2.20.1.9 Hatch cover types

(1) Single skin cover

A hatch cover made of steel or equivalent material that is designed to comply with ICLL Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is to be weathertight and fitted with gaskets and clamping devices unless specifically exempted from such fittings.

(2) Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

(3) Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with ICLL Regulation 15.

Note: Modern designs of lift-away hatch covers are in many cases called pontoon covers. This definition does not fit to the (3) above. Modern lift-away hatch covers are to fall into one of the two categories of single skin covers and double skin covers.

### 2.20.2 Weathertight steel hatch covers

2.20.2.1 General requirements

(1) These requirements are for all cargo hatch covers and coamings on exposed decks. As specified in this Section, parts of the requirements are for some specific ship types as categorized below:

① Type-1 ships, including all ships except bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.

② Type-2 ships, including all bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.

(2) The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and their closing arrangements.

(3) These requirements are applicable to hatch covers and coamings made of steel. The materials of hatch covers and hatch coamings are to meet the relevant requirements of Section 3, Chapter 1 of this PART. The material class I is to be applied for top plate, bottom plate and primary supporting members of hatch covers. Equivalent materials and novel designs subject to approval by CCS.

(4) Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting member. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement may be relaxed appropriately.

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(5) Unless stipulated otherwise, the thickness $t$ in these requirements is net thickness.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 2.20.2.3 to 2.20.2.6 and 2.20.2.8 of this Section.

The required gross thickness is obtained by adding the corrosion addition $t_s$, given in 2.20.2.10 of this Section, to the net thickness $t_s$.

Strength calculations using FEM are to be performed with net scantlings.

2.20.2.2 Hatch cover and coaming load model

The structural strength evaluation of hatch covers and hatch coamings is to be carried out using the design loads defined as follows:

Definitions:

$L$ = length of ship, in m;

$L_L$ = load line length, in m;

$x$ = longitudinal distance measured from midpoint of structural member to the aft end of $L$ or $L_L$, in m;

$D_{\min}$ = the least moulded depth, in m, as defined in Regulation 3 of ICLL Annex I;

$h_N$ = standard superstructure height, in m, to be calculated as follows:

$$h_N = 1.05 + 0.01L_L \text{, and} 1.8 \le h_N \le 2.3 .$$

(1) Vertical weather design load

The pressure $p_H$, in kN/m², on the hatch cover panel is given by ICLL. This may be taken from Table 2.20.2.2(1). The vertical weather design load is not to be combined with cargo loads in 2.20.2.2(3) and (4).

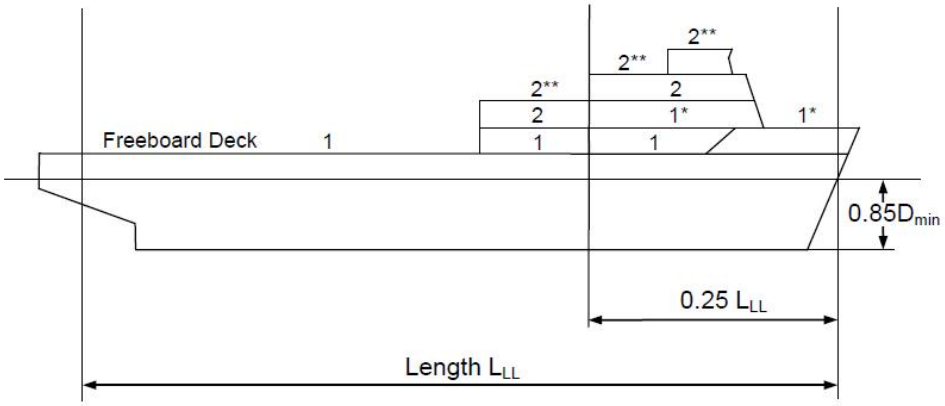
For Position 1 and Position 2, see Figure 2.20.2.2(1).

Where an increased freeboard is assigned, the design load for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided that the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height $h_N$ below the actual freeboard deck, see Figure 2.20.2.2(2).

**Vertical Design Load $p_H$ of Weather Deck Hatches Table 2.20.2.2(1)**

<table>
<tr><td rowspan="2">Position</td><td colspan="2">Vertical design load $p_H$ , kN/m$^2$</td></tr>
<tr><td>$\frac{x}{L_L} \le 0.75$</td><td>$0.75 < \frac{x}{L_L} \le 1.0$</td></tr>
<tr><td rowspan="6">1</td><td colspan="2">For $24\text{m} \le L_L \le 100\text{m}$</td></tr>
<tr><td rowspan="2">$\frac{9.81}{76}(1.5L_L + 116)$</td><td>On freeboard deck: $\frac{9.81}{76}\left[(4.28L_L + 28)\frac{x}{L_L} - 1.71L_L + 95\right]$</td></tr>
<tr><td>Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $\frac{9.81}{76}(1.5L_L + 116)$</td></tr>
<tr><td colspan="2">For $L_L$>100 m</td></tr>
<tr><td rowspan="3">$9.81\times3.5$</td><td>On freeboard deck for type B ships according to ICLL:<br>$9.81\left[(0.0296L_1 + 3.04)\frac{x}{L_L} - 0.0222L_1 + 1.22\right]$</td></tr>
<tr><td>On freeboard deck for ships with less freeboard than type B according to ICLL:<br>$9.81\left[(0.1452L_1 - 8.52)\frac{x}{L_L} - 0.1089L_1 + 9.89\right]$<br>$L_1$=$L_L$, but not more than 340 m</td></tr>
<tr><td>Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $9.81\times3.5$</td></tr>
</table>

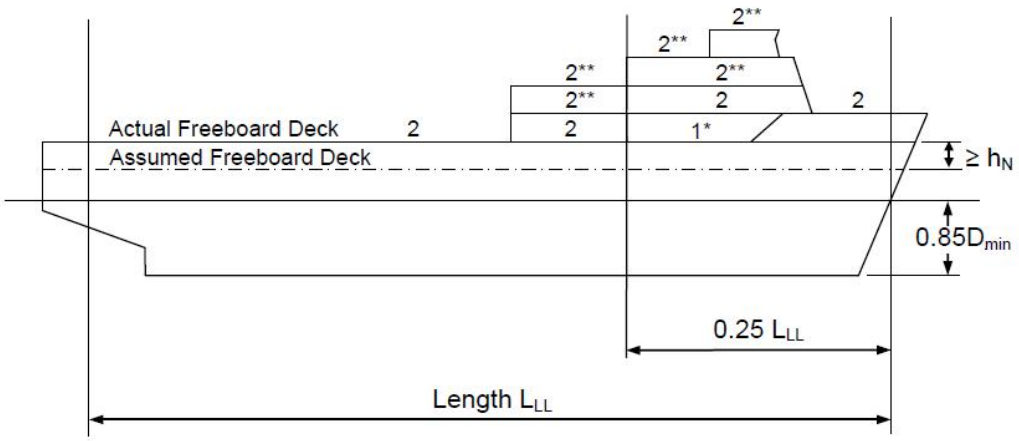
| | |
|---|---|
| 2 | For $24\ \text{m} \le L_L \le 100\ \text{m}$ |
| | $\frac{9.81}{76}(1.1L_L + 87.6)$ |
| | For $L_L$ >100 m |
| | $9.81 \times 2.6$ |
| | Upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck: $9.81 \times 2.1$ |




* — reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with $L_L$ > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

**Figure 2.20.2.2(1) Positions 1 and 2**




*— reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with $L_L$ > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

**Figure 2.20.2.2(2) Positions 1 and 2 for an Increased Freeboard**

(2) Horizontal weather design load

① General horizontal weather design load

The horizontal weather design load $p_A$ , in kN/m$^2$, for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is to be calculated by the following formula:

$$p_A = ac(bfc_L - z) \quad \text{kN/m}^2$$

where: $f = \frac{L}{25} + 4.1$, for $L$< 90 m;

$f = 10.75 - \left( \frac{300 - L}{100} \right)^{1.5}$, for $90\text{m} \le L < 300\text{m}$;

$f = 10.75$, for $300\text{m} \le L < 350\text{m}$;

$f = 10.75 - \left( \frac{L - 350}{150} \right)^{1.5}$, for $350\text{m} \le L \le 500\text{m}$;

$c_L = \sqrt{\frac{L}{90}}$, for $L < 90$ m;

$c_L = 1$, for $L \ge 90\text{m}$;

$a = 20 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates;

$a = 10 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height;

$a = 5 + \frac{L_1}{15}$, for side and protected front coamings and hatch cover skirt plates;

$a = 7 + \frac{L_1}{100} - \frac{8x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates abaft amidships;

$a = 5 + \frac{L_1}{100} - \frac{4x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates forward of amidships;

$L_1$=$L$, but need not be taken as greater than 300 m;

$b = 1.0 + \left( \frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2$, for $\frac{x'}{L} < 0.45$;

$b = 1.0 + 1.5 \left( \frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2$, for $\frac{x'}{L} \ge 0.45$;

$C_b$ — block coefficient, $0.6 \le C_b \le 0.8$, when determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, $C_b$ need not be taken less than 0.8;

$x'$ — distance in m, between the transverse coaming or hatch cover skirt plate considered and aft end of the length $L$. For side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0.15 $L$ each, and "$x$" is to be taken as the distance between aft end of the length $L$ and the centre of each part considered;

$z$ — vertical distance, in m, from the summer load line to the midpoint of stiffener span, or to the middle of the plate field;

$c = 0.3 + 0.7\frac{b'}{B'}$, the $\frac{b'}{B'}$ is not to be less than 0.25;

$b'$ — breadth of coaming, in m, at the position considered;

$B'$ —actual maximum breadth of ship, in m, on the exposed weather deck at the position considered.

The horizontal design load is not to be taken less than the minimum values given in Table 2.20.2.2(2).

**Minimum Horizontal Design Load $P_{Amin}$** **Table 2.20.2.2(2)**

| $L$ | $P_{Amin}$ kN/m² | |
|---|---|---|
| | Unprotected fronts | elsewhere |
| ≤ 50m | 30 | 15 |
| > 50m | $25+\frac{L}{10}$ | $12.5+\frac{L}{20}$ |
| < 250m | | |
| ≥ 250m | 50 | 25 |

② Horizontal weather design load applicable to coamings of Type-2 ships

The pressure $P_{coam}$, in kN/m², on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220$ kN/m², when a forecastle is fitted in accordance with Section 13, Chapter 8, PART TWO of CCS Rules for Classification of Sea-going Steel Ships;

$P_{coam} = 290$ kN/m² in the other cases;

The pressure $P_{coam}$, in kN/m², on the other coamings is given by:

$P_{coam} = 220$ kN/m²

Note: The horizontal weather design loads $p_A$ and $P_{coam}$ need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.

(3) Cargo loads

① Distributed loads

The uniform cargo load on hatch covers due to cargo loads $p_L$, resulting from heave and pitch (i.e. ship in upright condition) is to be determined according to the following formula:

$$p_L = p_C(1 + a_V) \quad \text{kN/m}^2$$

where: $p_C$ — uniform cargo load, in kN/m²;

$a_V$ — vertical acceleration addition as follows:

$a_V = Fm$;

$F = \frac{0.11v_0}{\sqrt{L}}$;

$$m = m_0 - 5(m_0 - 1)\frac{x}{L} \quad \text{for} \quad 0 \le \frac{x}{L} \le 0.2;$$

$$m = 1.0 \text{ for } \quad 0.2 < \frac{x}{L} \le 0.7;$$

$$m = 1 + \frac{m_0 + 1}{0.3}\left[\frac{x}{L} - 0.7\right] \quad \text{for} \quad 0.7 < \frac{x}{L} \le 1.0;$$

$$m_0 = 1.5 + F;$$

$v_0$ — maximum speed at summer load line draught, is not to be taken less than $\sqrt{L}$, in kn.

② Point loads

The load $P$, in kN, due to a concentrated force $P_S$, in kN, except for container load, resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = P_S(1 + a_V) \quad \text{kN}$$

(4) Container loads

① The loads defined in ② to ④ are to be applied where containers are stowed on the hatch cover.

② Corner loads for ship in upright condition

The load $P$, in kN, applied at each corner of a container stack, and resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = 9.81\frac{M}{4}(1 + a_V) \quad \text{kN}$$

where: $a_V$ — vertical acceleration addition according to (3)①;

$M$ — maximum designed mass of container stack, in t.

③ Corner loads for ship in heel condition

Where containers are stowed on hatch covers, the loads due to heave, pitch and the ship's rolling motion are to be determined as follows (see Figure 2.20.2.2(4)):

$$A_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 - 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 + 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_y = 2.4M \quad \text{kN}$$

where:

$a_V$ — vertical acceleration addition according to 2.20.2.2(3);

$M$ — maximum designed mass of container stack, in t;

$h_m$ — designed height of centre of gravity of stack above hatch cover top, in m, may be calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container, $= \sum(z_i \cdot W_i)/M$;

$z_i$ — distance from hatch cover top to the centre of $i$th container, in m;

$W_i$ — mass of $i$th container, in t;

$b$ — distance between foot points, in m;

$A_z$, $B_z$ — support forces in $z$-direction at the forward and aft stack corners;

$B_y$ — support forces in $y$-direction at the forward and aft stack corners.

Values of $A_z$ and $B_z$ applied for the hatch cover strength evaluation are to be shown in the drawings of the hatch covers.

Note: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

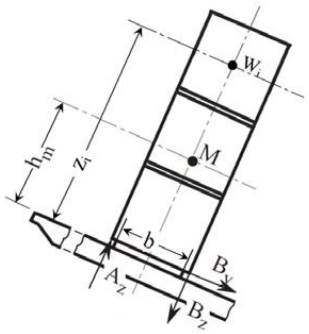



**Figure 2.20.2.2(4)**

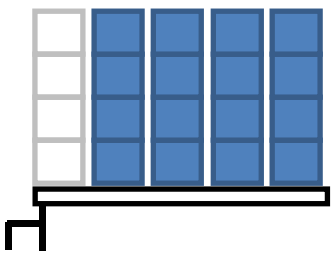
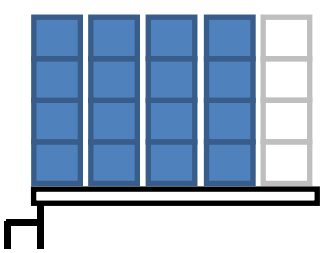
④ Load cases with partial loading

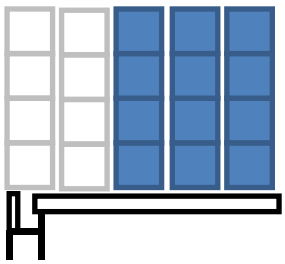
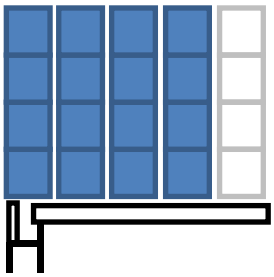
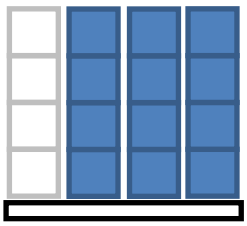
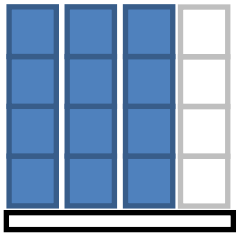
The load cases in ② and ③ above are also to be considered for partial non-homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Table 2.20.2.2(4), are to be considered. The load case of partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks may be neglected, refer to Table 2.20.2.2(4) Partial loading of container hatch covers.

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. Therefore, CCS may require that additional partial load cases other than those in Table 2.20.2.2(4) be considered.

**Partial loading of container hatch covers** **Table 2.20.2.2(4)**

| Heel direction | ← | → |
|---|---|---|
| Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover |  |  |

| Heel direction | ← | → |
|---|---|---|
| Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions |  |  |
| Hatch covers not supported by the longitudinal hatch coaming (center hatch covers) |  |  |

⑤ Mixed stowage of 20’ and 40’ containers on hatch cover

In the case of mixed stowage (20'+40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40’ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20’ containers.

(5) Hatch covers, which in addition to the loads according to (1) to (4) above are loaded in the ship’s transverse direction by forces due to elastic deformations of the ship’s hull, are to be designed such that the sum of stresses does not exceed the allowable value given in 2.20.2.5.

2.20.2.3 The net structural scantling of weathertight steel hatch covers is to be in compliance with the following requirements:

(1) Local net plate thickness

The local net plate thickness of the hatch cover top plating is not to be less than that obtained from the following formulae, and not less than 6 mm:

$$t = 0.0158F_p s\sqrt{\frac{p}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 0.01s \quad \text{mm}$$

where: $F_p$ — factor for combined membrane and bending response, calculated as follows:

$F_p = 1.5$ in general;

$F_p = 1.9\dfrac{\sigma}{\sigma_a}$ for $\dfrac{\sigma}{\sigma_a} \geq 0.8$ for the attached plate flange of primary supporting members;

$s$ — stiffener spacing, in mm;

$p$ — pressure $p_H$ and $p_L$, calculated according to 2.20.2.2 of this Section, in kN/m$^2$;

$\sigma$ — maximum normal stress of hatch cover top plating, in N/mm$^2$, determined according to Figure 2.20.2.3;

$\sigma_a$——permissible stress, see Table 2.20.2.5, in N/mm$^2$;

$R_{eH}$ — yield stress of materials, in N/mm$^2$.

For flange plates under compression, the buckling strength requirements of 2.20.2.6 of this Section are to be complied with.

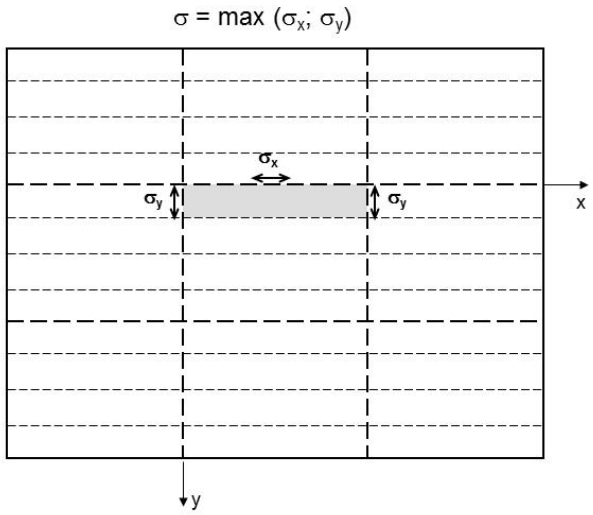



**Figure 2.20.2.3**

① The local net plate thickness of hatch covers for wheel loading is also to meet the relevant requirements of Section 21 of this Chapter.

② The local net plate thickness of lower plating of double skin hatch covers and box girders are to comply with the following requirements:

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm, of lower plating is to be taken not less than 5 mm. When project cargo is intended to be carried on a hatch cover, the net thickness is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

where: $s$— stiffener spacing, in mm.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is not to be less than 5 mm.

Note:

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that may be considered as uniformly distributed over the hatch cover, e.g. timber, pipes or steel coils need not to be considered as project cargo.

(2) The stiffeners of hatch covers are to comply with the following requirements:

The net section modulus $Z$ and net shear area $A_{shr}$ of uniformly loaded hatch cover stiffeners constrained at both ends are not to be less than:

$$Z = \frac{psl^2}{f_{bc}\sigma_a} \quad \text{cm}^3$$

$$A_{shr} = \frac{8.7psl}{\sigma_a}10^{-3} \quad \text{cm}^2$$

where: $l$ — secondary stiffener span, in m, to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge

support, as applicable. When brackets are fitted at both ends of all stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the unsupported span, for each bracket;

$s$ — spacing of stiffeners, in mm;

$p$ — $p_H$ and $p_L$, to be calculated according to 2.20.2.2 of this Section, in kN/m$^2$;

$f_{bc}$ — boundary coefficient of stiffener, taken equal to:

$f_{bc}$ = 8, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end;

$f_{bc}$ = 12, in the case of stiffener clamped at both ends.

$\sigma_a$ — allowable stress as defined in Tab.2.20.2.5, in N/mm$^2$.

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened according to CCS requirements.

The net thickness, in mm, of the stiffener (except U-beams/trapeze stiffeners) web is not to be less than 4 mm.

The net section modulus of secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

Stiffeners parallel to primary supporting members are to be continuous at crossing primary supporting members, and may be considered for calculations regarding cross-sectional properties of primary members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the allowable stresses according to 2.20.2.5 of this Section. When the lower plating is not taken into account as a strength member of the hatch cover, the requirements of this paragraph are not necessary for the stiffeners of lower plating.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.20.2.6 of this Section is to be verified.

For hatch covers subject to wheel loading, the relevant requirements of Section 21 of this Chapter are to be complied with. For hatch covers subject to point loads, stiffener scantlings are to be determined by direct calculations under consideration of the allowable stresses as required in 2.20.2.5 of this Section.

(3) The net scantlings of primary supporting members are to comply with the following requirements:

① Scantlings of primary supporting members are to be obtained from direct calculations according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

For all components of primary supporting members sufficient safety against buckling is to be verified according to 2.20.2.6 of this Section. For biaxially compressed flange plates,

the buckling strength is to be verified within the effective width according to 2.20.2.6(3)② of this Section.

The net thickness, in mm, of webs of primary supporting members is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

$$t = 5 \quad \text{mm}$$

where: $s$— spacing of stiffeners, in mm.

② The net scantlings of edge girders are to comply with the following requirements:

Scantlings of edge girders are to be verified according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

The net thickness of the outer edge girders exposed to wash of seawater is not to be less than the largest of the following values:

$$t = 0.0158s\sqrt{\frac{p_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 8.5s \times 10^{-3} \quad \text{mm}$$

$$t = 6 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in mm;

$P_A$ — horizontal weather design pressure, calculated according to 2.20.2.2 of this Section, in kN/m$^2$;

For the required moment of inertia of edge girders, refer to 2.20.2.9(1)④.

2.20.2.4 Strength calculation

The stresses in hatch covers are to be determined by FE analysis.

The stress calculation model in this section is to be used for both yielding and buckling strength assessments in accordance with 2.20.2.5 and 2.20.2.6, respectively.

The net scantlings as defined in 2.20.2.1(5) are to be used.

(1) General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. In no case element width is to be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 3.

The element height of webs of primary supporting members is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 2.20.2.4(1) are to be assessed by means of FE analysis.The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

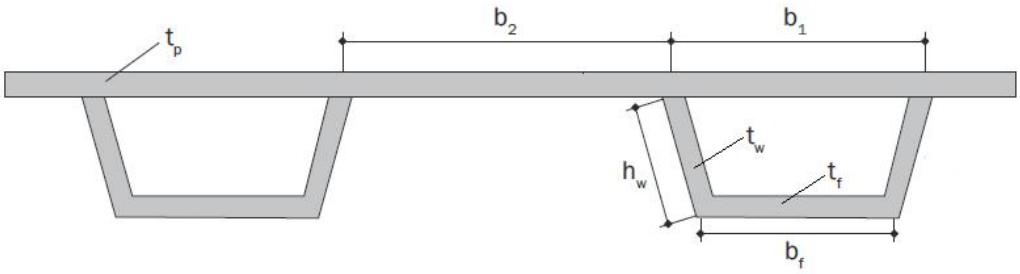



Figure. 2.20.2.4(1) Example of hatch cover fitted with U-type stiffeners

① A right-handed coordinate system is to be used with:

the *x*-axis measured in the longitudinal direction, positive forward;

the *y*-axis measured in the transverse direction, positive to port from the centerline;

the *z*-axis measured in the vertical direction, position upward.

② The FEM is to be performed with net scantlings.

③ The finite element model is to be limited as follows:

(a) for symmetry of the hatch cover girders, loads and supporting boundary conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check;

(b) for non-symmetry of hatch cover girders, loads or supporting boundary conditions about any of the axes, the whole hatch cover may be taken for strength evaluation, see Figure 2.20.2.4(2).

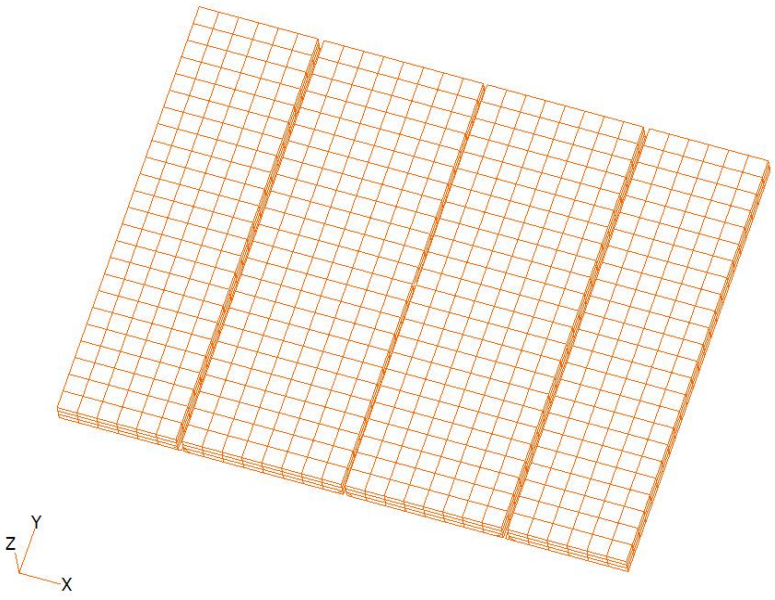



**Figure 2.20.2.4(2) Finite Element Hatch Cover Model**

④ The model element is to comply with the following requirements:

(a) all plating, including girders and stiffeners, is to be represented by the finite element model;

(b) all plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible;

(c) all stiffeners are to be modeled using beam, rod or plate elements.

⑤ The element mesh size is to be controlled as follows:

(a) the mesh size is not to be greater than the spacing of stiffeners;

(b) the girders are to be represented by at least 3 elements in the depth;

(c) triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.

⑥ Boundary conditions are to be determined as follows:

(a) for symmetry of the hatch cover girders and loads about the xz-plane, the longitudinal displacement of nodes in the symmetric plane and the rotations about the *y* and *z* axes are to be taken as 0 respectively, i.e. $\delta_x = \theta_y = \theta_z = 0$, as shown in Figure 2.20.2.4(3);

(b) for symmetry of the hatch cover girders and loads about the yz-plane, the transverse displacement of nodes in the symmetric plane and rotation about the *x* and *z* axes are to be taken as 0 respectively i.e. $\delta_y = \theta_x = \theta_z = 0$, as shown in Figure 2.20.2.4(3);

(c) boundary nodes in way of bearing pads on the hatch coamings are generally to be fixed against displacement in the *z* direction, i.e. $\delta_z = 0$;

(d) lifting stoppers are to be fixed against displacements in the direction determined by the stoppers;

(e) hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the *z* direction.

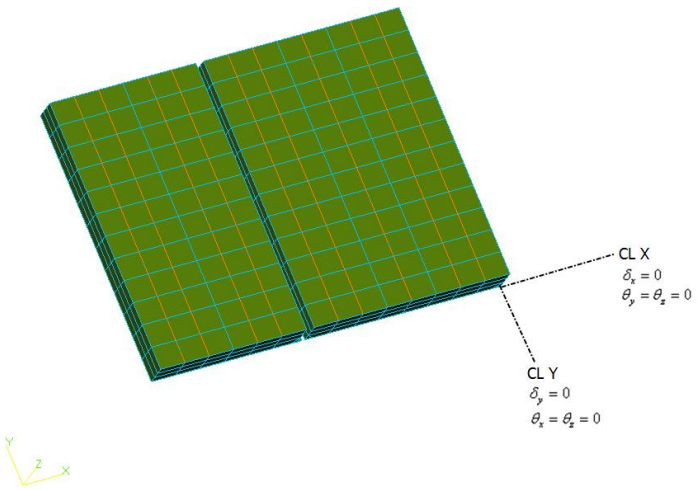



**Figure 2.20.2.4(3) Boundary Conditions of Hatch Cover Model**

2.20.2.5 Yield strength and deflection criteria of hatch cover structures

(1) Allowable stresses

All hatch cover structures are to comply with the following formulae:

$\sigma_{vm} \le \sigma_a$, for shell element;

$\sigma_{axial} \le \sigma_a$, for rod or beam elements.

where: $\sigma_a$ ——allowable stress in Table 2.20.2.5;

$R_{eH}$ ——yield stress of the material;

$\sigma_{vm}$ ——the equivalent stress may be taken as follows:

$$\sigma_V = \sqrt{\sigma_x^{\ 2} - \sigma_x \cdot \sigma_y + \sigma_y^{\ 2} + 3\tau^2} \qquad \text{N/mm}^2$$

where: $\sigma_x$ — normal stress, in N/mm$^2$, in $x$-direction;

$\sigma_y$ — normal stress, in N/mm$^2$, in $y$-direction;

$\tau$ — shear stress, in N/mm$^2$, in the $x$-$y$ plane;

$\sigma_{axial}$ —axial stress in rod or beam elements, in N/mm$^2$.

In case of FEM calculations using shell or plane strain elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges is not to exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

For steels with a yield stress of 390 N/mm$^2$, it is taken as 368 N/mm$^2$ for calculation.

Stress concentrations are to be evaluated according to the actual conditions.

Allowable stress Table 2.20.2.5

| Members of | Subject to | $\sigma_a$ , in N/mm$^2$ |
|---|---|---|
| Hatch cover structure | External pressure, as defined in 2.20.2.2(1) | $0.80R_{eH}$ |
| | Other loads, as defined in 2.20.2.2(2)~(5) | $0.90R_{eH}$ for static+dynamic load case<br>$0.72R_{eH}$ for static load case |

(2) Deflection

The vertical deflection of primary supporting members due to the load stipulated in 2.20.2.2 of this Section is to be not more than 0.0056 $l_g$, where $l_g$ is the greatest span of primary supporting member.

Note: Where containers are arranged on hatch covers and mixed stowage is allowed, i.e., a 40'-container stowed on top of two 20'-containers, particular attention is to be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with cargo in hold has to be considered.

2.20.2.6 Buckling strength of hatch cover structures

(1) General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be performed in compliance with the requirements in Appendix 5.

The net scantlings as defined in 2.20.2.1(5) are to be used for buckling check.

(2) Slenderness requirements

The slenderness requirements are to be in accordance with those specified in Sec 2 of Appendix 5.

The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) Buckling requirements

① These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of opening.

The buckling strength assessment of coaming parts is to be done according to this paragraph.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 2.20.2.6(3)②-2.20.2.6(3)⑤, respectively. The procedure and detailed requirements for buckling assessment are given in Section 4 of Appendix 5, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 2.20.2.6(3) are defined in Appendix 5.

② Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in 4.2, Section 4 of Appendix 5. Assessment Method A (-A) and Method B (-B) as defined in 1.3, Section 1 of Appendix 5 are to be used in accordance with Table 2.20.2.6(3)①, Figure 2.20.2.6(3)① and Figure 2.20.2.6(3)②. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in 5.2.5, Section 5 of Appendix 5 are also to be followed.

**Structural members and assessment methods** **Table 2.20.2.6(3)①**

| Structural elements | Assessment method[(1)(2)] | Normal panel definition |
|---|---|---|
| Hatch cover top/bottom plating structures, see Figure 2.20.2.6(3)① | | |
| Hatch cover top/bottom plating | SP-A | Length: between transverse girders<br>Width: between longitudinal girders |
| Irregularly stiffened panels | UP-B | Plate between local stiffeners/PSM |
| Hatch cover web panels of primary supporting members, see Figure 2.20.2.6(3)② | | |
| Web of transverse/longitudinal girder (single skin type) | UP-B | Plate between local stiffeners/face plate/PSM |
| Web of transverse/longitudinal girder (double skin type) | SP-B[(3)] | Length: between PSM<br>Width: full web depth |
| Web panel with opening | Procedure for | Plate between local stiffeners/face plate/PSM |

| | | |
|---|---|---|
| | opening | |
| Irregularly stiffened panels | UP-B | Plate between local stiffeners/face plate/PSM |
| Note 1: SP and UP stand for stiffened and unstiffened panel respectively.<br>Note 2: A and B stand for Method A and Method B respectively.<br>Note 3: In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used. | | |

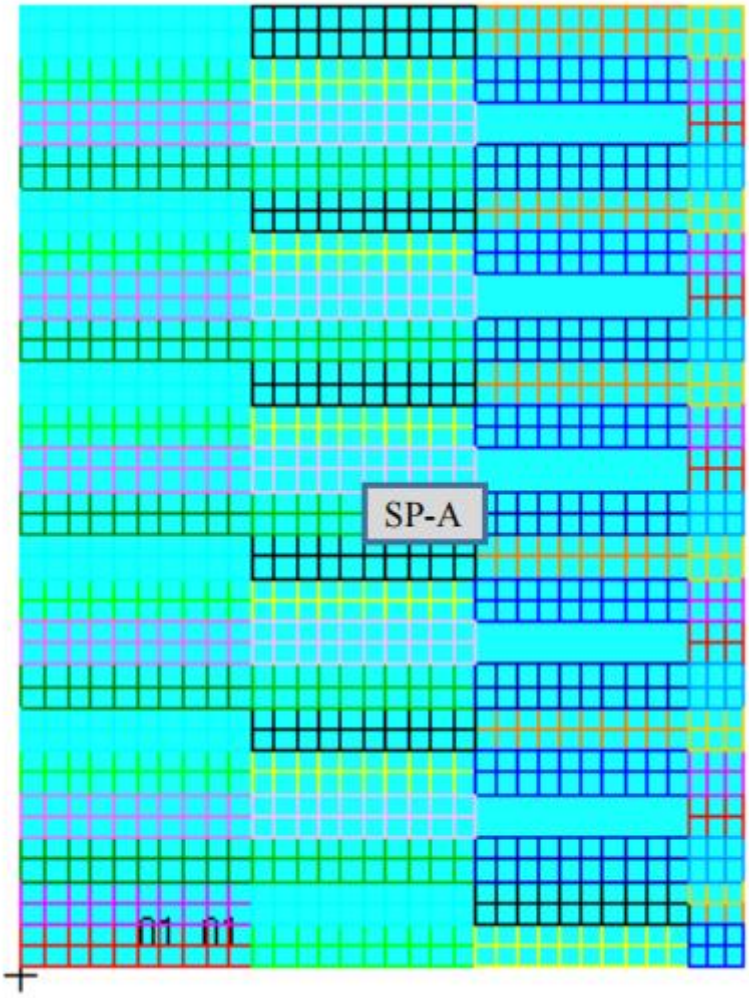



Figure 2.20.2.6(3)①

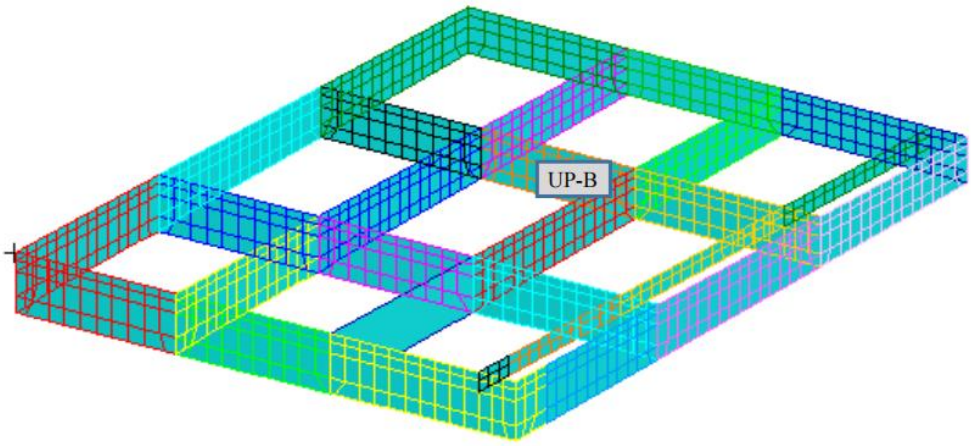



Figure 2.20.2.6(3)②

③ Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and 2.2, and stresses obtained from FE analysis, refer to 2.20.2.4.

④ Safety factors

For all hatch cover structural members, safety factor S=1.0 is to be applied to both of the plating and stiffener buckling capacity formulas as defined in 5.2.2, Section 5 of Appendix 5 and 5.2.3, Section 5 of Appendix 5, respectively.

⑤ Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where: $\eta_{act}$ —— Buckling utilisation factor based on the applied stress, as defined in 1.3.2.2, Section 1 of Appendix 5 and Section 4 of Appendix 5, and calculated per Section 5 of Appendix 5.

$\eta_{all}$ —— Allowable buckling utilisation factor, taken as given in Tab.2.20.2.6(3)⑤.

**Allowable buckling utilisation factors** **Table 2.20.2.6(3)⑤**

| Structural component | Subject to | $\eta_{all}$, allowable buckling utilisation factor |
|---|---|---|
| Plates and stiffeners<br>Web of PSM | External pressure, as defined in 2.20.2.2(1) | 0.80 |
| | Other loads, as defined in 2.20.2.2(2)~(5) | 0.90 for static+dynamic load case<br>0.72 for static load case |

2.20.2.7 Details of hatch covers

(1) Container foundation on hatch covers

Container foundations on hatch covers are to be in compliance with the relevant requirements of Appendix 1 of Chapter 7 of this PART. The calculated stresses of substructures of container foundations under cargo and container loads according to 2.20.2.2 of this Section are to comply with the requirements of 2.20.2.5 of this Section.

(2) Weathertightness

In addition to the following requirements, the hatch covers are also to meet the relevant requirements of IACS REC14.

① Packing material (general)

The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations may be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

② Dispensation of weathertight gaskets

For hatch covers of cargo holds intended solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to 2.20.2.7(2) may be dispensed with:

- The hatchway coamings are to be not less than 600 mm in height.
- For weather deck hatch covers located above a depth $H(x)$, $H(x)$ is to comply with the following criterion:

$$H(x) \geq T_{fb} + f_b + h \qquad \text{m}$$

where: $T_{fb}$ — draught, in m, corresponding to the assigned summer load line;

$f_b$ — minimum required freeboard, in m, determined in accordance with ICLL Regulation 28 as modified by further regulations as applicable;

$$h = 4.6 \text{ m} \qquad \text{for } \frac{x}{L_L} \leq 0.75;$$

$$h = 6.9 \text{ m} \qquad \text{for } \frac{x}{L_L} > 0.75.$$

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels, the clear opening of the gap in between the panels is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system, refer to the relevant requirements of Chapter 6, PART EIGHT of the Rules.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be complied with for the storage and segregation of containers carrying dangerous goods.

③ Cross-joint of multi-panel covers are to be provided with efficient drainage arrangements.

2.20.2.8 Hatch coamings are to comply with the following requirements:

(1) The net thickness of weather deck hatch coamings is not to be less than the larger of the following values:

- For Type-1 ships:

$$t = 0.0142s\sqrt{\frac{p_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 6 + \frac{L_1}{100} \quad \text{mm}$$

- For Type-2 ships:

$$t = 0.016s\sqrt{\frac{p_{coam}}{0.95R_{eH}}} \quad \text{mm}$$

$$t_{\min} = 9.5 \quad \text{mm}$$

where: $s$ — stiffener spacing, in mm;

$P_A$ — horizontal weather design load, in kN/m$^2$, to be calculated according to 2.20.2.2(2) ① of this Section;

$p_{coam}$ ——horizontal weather design load, in kN/m$^2$, to be calculated according to 2.20.2.2(2)② of this Section;

$L_1 = L$, but need not be taken as greater than 300 m.

The continuous longitudinal hatch coamings within 0.4$L$ amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(2) The stiffeners of hatch coaming are to meet the following requirements:

The stiffeners are to be continuous at the coaming stays.

For stiffeners with both ends constrained, the net section modulus $Z$ and net shear area $A_{shr}$, calculated on the basis of net thickness, are not to be less than:

- For Type-1 ships:

$$Z = \frac{p_A s l^2}{f_{bc} R_{eH}} \quad \text{cm}^3$$

$$A_{shr} = \frac{p_A s l^2}{R_{eH}} 10^{-2} \quad \text{cm}^2$$

where: $f_{bc}$ =12 in general

= 8 for the end spans of stiffeners sniped at the coaming corners;

$l$ — stiffener span, in m, to be taken as the spacing of coaming stays;

$s$ — stiffener spacing, in mm;

$P_A$ — horizontal weather design load, in kN/m$^2$, to be calculated according to 2.20.2.2(2) ① of this Section.

For sniped stiffeners of coaming at hatch corners, section modulus and shear area at the fixed support have to be increased by 35%. The gross thickness of the coaming plate at the sniped stiffener end is not to be less than:

$$t_{gr} = 19.6\sqrt{\frac{p_A s\left(l - 0.0005s\right)}{1000R_{eH}}} \quad \text{mm}$$

- For Type-2 ships:

$$Z = 1.21\frac{p_{coam} s l^2}{f_{bc} c_p R_{eH}} \quad \text{cm}^3$$

where: $f_{bc}$ —16 in general
12 for the end spans of stiffeners sniped at the coaming corners;

$l$ —stiffener span, in m, to be taken as the spacing of coaming stays;

$s$ — stiffener spacing, in mm;

$P_A$ — horizontal weather design load, in kN/m$^2$, to be calculated according to 2.20.2.2(2)① of this Section;

$p_{coam}$ — horizontal weather design load, in kN/m$^2$, to be calculated according to 2.20.2.2(2)② of this Section;

$c_p$ — ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40$t$, where $t$ is the plate net thickness

$c_p$ — 1.16 in the absence of more precise evaluation

The horizontal stiffeners of continuous longitudinal hatch coamings within 0.4$L$ amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(3) Coaming stays are to be designed for the loads transmitted through them and are to comply with the following requirements, in addition to the allowable stresses stipulated in 2.20.2.5 of this Section.

① Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus Z, in cm$^3$, and the gross thickness $t_w$, in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Figure 2.20.2.8(3)) are to be taken not less than:

$$Z = \frac{P s_c H_c^2}{1.9 R_{eH}} \quad \text{cm}^3$$

$$t_w = \frac{2 P s_c H_c}{h R_{eH}} \quad \text{mm}$$

where: $H_C$ — stay height, in m;

$s_{cs}$ — stay spacing, in mm;

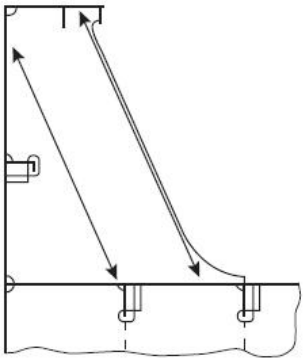
$h$ — stay depth, in mm, at the connection with the deck;

$p$ — pressure on coaming, in kN/m$^2$ , taken as $p_A$ defined in 2.20.2.2(2)① in general and as $p_{coam}$ defined in 2.20.2.2(2)② for Type-2 ships.

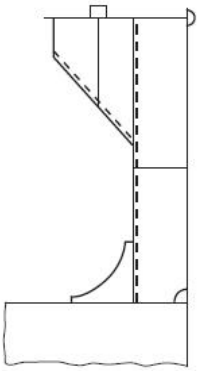
For other designs of coaming stays, such as those shown in Figure 2.20.2.8(3), examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 2.20.2.5 of this Section.

Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation of section modulus of coaming stays if an appropriate substructure is provided and welding provides an adequate joint.

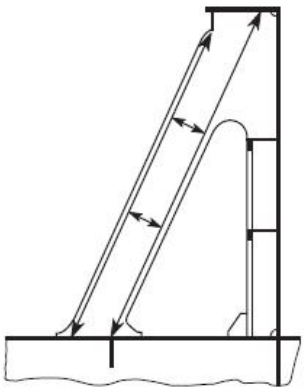
Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than $0.44t_w$. For Type-2 ships, toes of stay webs are to be connected to the deck plating with full or partial penetration double bevel welds extending over a distance not less than 15% of the stay width. For other ship types the size of welding for toes of webs at the lower end of coaming stays is to comply with the relevant requirements of Chapter 1 of this PART.



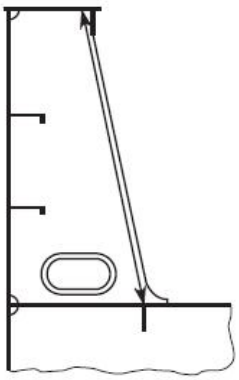
Example 1



Example 2



Example 3



Example 4

**Figure 2.20.2.8(3) Examples of coaming stays**

② For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered.

(4) The hatch coaming is also to comply with the following requirements:

① Hatch coamings which are part of the longitudinal hull structure are to be designed according to the relevant requirements of Section 2 of this Chapter.

② For structural members welded to coamings and for cutouts in the top of coamings, sufficient fatigue strength is to be verified.

③ Longitudinal hatch coamings with a length exceeding $0.1L$ are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

④ The local details are to be designed to transfer the loads on the hatch covers to the hatch coamings, and, through them, to the deck structures below. Hatch coamings and supporting

structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions. Structures under deck are to be checked against the load transmitted by the stays. Unless otherwise stated, welding and material are to comply with the relevant requirements of CCS.

⑤ On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m apart.

⑥ Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. See Figure 2.20.2.8(4).

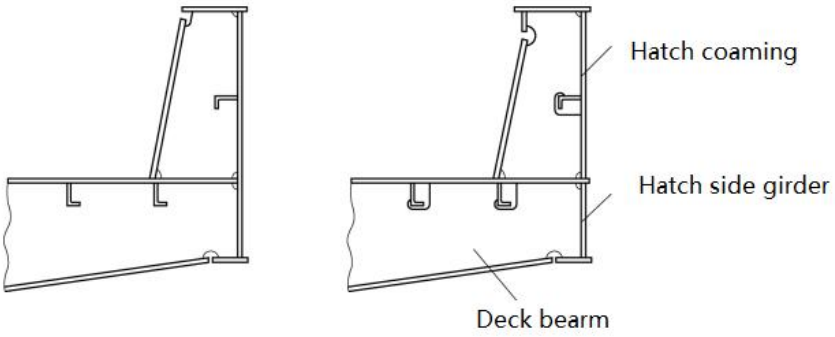



**Figure 2.20.2.8(4) Example for the Extension of Coaming Plates**

⑦ Drainage arrangement at the coaming is to comply with the following requirements:

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch covers, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

2.20.2.9 Closing arrangements of weathertight steel hatch covers

(1) Securing arrangements

① General requirements

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained. Securing devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics. According to the requirements of 2.20.2.3(3)② of this Section, a sufficient number of securing devices is to be provided at each side of the hatch cover, including that consisting of several parts.

The materials of stoppers, securing devices and their welding are to comply with the relevant requirements of CCS Rules for Materials and Welding. Specifications of the materials are to be shown in the drawings of the hatch covers.

② Rod cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

③ Hydraulic cleats

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

④ Cross-sectional area of the securing devices

The gross cross-sectional area of the securing devices is not to be less than:

$$A = 0.28 q S_{SD} k_l \qquad \text{cm}^2$$

where: $q$ —packing line pressure, in N/mm, minimum 5 N/mm;

$S_{SD}$ — spacing between securing devices, in m, not to be taken less than 2 m;

$k_l = (\frac{235}{R_{eH}})^e$;

$R_{eH}$ — the minimum yield stress of material, in N/mm$^2$, but not to be taken greater than $0.7 R_m$;

$R_m$ — tensile strength of material, in N/mm$^2$;

$e$ =0.75 for $R_{eH} > 235$ N/mm$^2$;

$e$ =1.00 for $R_{eH} \le 235$ N/mm$^2$.

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5m$^2$ in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 2.20.2.9(1)⑤. The design load is taken as the packing line pressure $q$ multiplied by the spacing $S_{SD}$ between securing devices.

⑤ Anti-lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 2.20.2.2(4) of this Section, refer to Figure 2.20.2.9(1). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_V = \frac{150}{k_l} \qquad \text{N/mm}^2$$

where: $k_l$ — as in 2.20.2.9(1)④.

Note: The partial load cases given in Table 2.20.2.2(4) may not cover all unsymmetrical loadings, critical for hatch cover lifting.

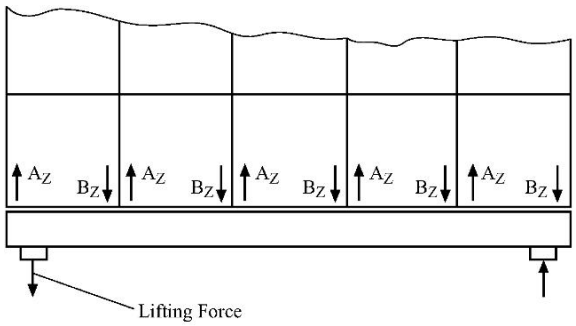



**Figure 2.20.2.9(1) Lifting Forces at a Hatch Cover**

The anti-lifting devices may be dispensed with according to the following requirements:
In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for hatch covers may be omitted. In such cases, it is to be proven by means of grillage or finite element analysis that an equilibrium condition is achieved using compression only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height $h_E$, as shown in Figure 2.20.2.9(2), where $h_E$ is not to be less than:

$$h_E = 1.75(2se + d^2)^{0.5} - 0.75d \quad \text{mm}$$

$$h_{E\min} = \text{height of the cover edge plate} + 150 \quad \text{mm}$$

where: $e$ — largest distance from the inner edge of the transverse cover guide to the end of the cover edge plate, in mm;

$s$ — total clearance within the transverse cover guide, with $10 \le s \le 40$, in mm;

$d$ — distance between upper edge of transverse stopper and hatch cover support, in mm.

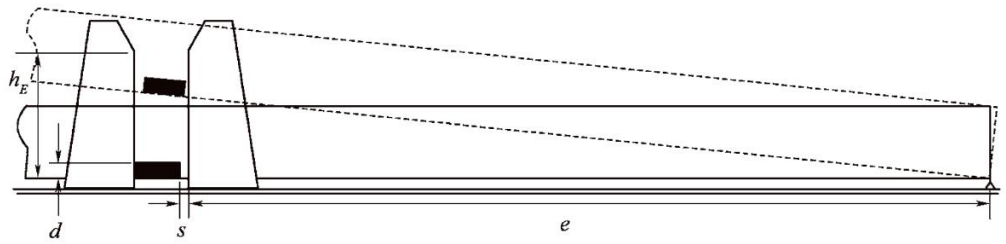



**Figure 2.20.2.9(2) Height of Transverse Cover Guide**

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height $h_E$.

(2) Hatch cover supports, stoppers and supporting structures

① Horizontal mass forces

For the design of hatch cover supports, the horizontal mass force is to be taken as follows:

$$F_h = ma$$

where: $F_h$— horizontal mass force, in kN;

$a_X = 0.2g$ in longitudinal direction;

$a_Y = 0.5g$ in transverse direction;

$m$— sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

The accelerations in longitudinal direction and in transverse direction need not be considered as acting simultaneously.

② Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2.20.2.2 of this Section and of the horizontal mass forces specified in (2)①, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the values obtained from the following formula:

$$p_{n\max} = dp_n \qquad \text{N/mm}^2$$

where: $d$ = 3.75-0.015$L$;

$d_{\max} = 3.0$;

$d_{\min} = 1.0$, in general;

$d_{\min} = 2.0$, for partial loading conditions, see 2.20.2.2(5);

$P_n$ — Allowable nominal surface pressure, see Table 2.20.2.9(2).

**Allowable Nominal Surface Pressure $P_n$ Table 2.20.2.9(2)**

| Support material | $P_n$ (N/mm$^2$) when loaded by | |
|---|---|---|
| | Vertical force | Horizontal force (on stoppers) |
| Hull structural steel | 25 | 40 |
| Hardened steel | 35 | 50 |
| Lower friction materials | 50 | — |

For metallic supporting surfaces not subjected to relative displacements, the following nominal surface pressure applies:

$$p_{n\max} = 3p_n \qquad \text{N/mm}^2$$

Note: When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion is to be assumed and agreed with CCS.

Drawings of the supports are to be submitted for approval. In the drawings of supports, the permitted maximum pressure given by the material manufacturer is to be indicated.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low friction properties is recommended.

The substructures of the supports are to be of such a design that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force $P_h$ in the longitudinal and transverse direction:

$$P_h = \mu \cdot \frac{P_V}{\sqrt{d}}$$

where: $P_V$ — vertical supporting force;

$\mu$ — frictional coefficient;

$\mu$ = 0.5 steel to steel.

For non-metallic, low-friction support materials on steel, the friction coefficient $\mu$ may be reduced but not to be less than 0.35 and it is to be submitted for approval.

Supports as well as the adjacent structures and substructures are to be designed such that the allowable stresses in 2.20.2.5 of this Section are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces $P_h$, a fatigue strength is to be considered.

③ Hatch cover stoppers

Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 2.20.2.2(2) of this Section and 2.20.2.9(2)① is to be applied for the dimensioning of the stoppers and their substructures.

The allowable stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 2.20.2.5 of this Section and in addition, the requirements in 2.20.2.9(2)② are to be taken into consideration.

Specifically for Type-2 ships, the following additional requirements are to be complied with:

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m$^2$.

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m$^2$.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m$^2$.

This pressure may be reduced to 175 kN/m$^2$ when a forecastle is fitted in accordance with Section 13, Chapter 8, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of 0.8$R_{eH}$.

2.20.2.10 Corrosion addition and steel renewal

(1) Corrosion addition for hatch covers and hatch coamings

For scantlings of hatch cover components, the general corrosion additions $t_S$, as shown in Table 2.20.2.10, is required.

**Corrosion Addition $t_S$ for Hatch Covers and Hatch Coamings Table 2.20.2.10**

| Application | Structure | $t_S$[mm] |
|---|---|---|
| Weather deck hatches of container ships, car carriers, paper carriers and passenger vessels | Hatch covers | 1.0 |
| | Hatch coamings | 1.5 for $t \le 10$ |
| | | $\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$ |
| Weather deck cargo hatches of Type-2 ships | Hatch covers in general | 2.0 |
| | Top and bottom plating of double skin hatch covers | 2.0 |
| | Internal structure of double skin hatch covers | 1.5 |
| | Hatch coamings and coaming stays | 1.5 |
| Weather deck hatches of all other ships | Hatch covers in general | 2.0 |
| | Weather exposed plating and bottom plating of double skin hatch covers | 1.5 |
| | Internal structure of double skin hatch covers and closed box girders | 1.0 |
| | Hatch coamings not part of the longitudinal hull structure | 1.5 |
| | Hatch coamings part of the longitudinal hull structure | 1.5 for $t \le 10$ |
| | | $\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$ |
| | Coaming stays and stiffeners | 1.5 |

Notes:

*t*: net thickness of hatch coaming required by the Rules.

*K*: material factor.

(2) Steel renewal

Steel renewal is required where the gauged thickness is less than $t_{net}$ + 0.5 mm for

- single skin hatch covers,
- the plating of double skin hatch covers, and
- coaming structures the corrosion additions $t_S$ of which are given in Table 2.20.2.10.

Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15), Chapter 5 of PART ONE of the Rules.

For internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when it is deemed necessary by surveyor, on the basis of the plating corrosion or deformation. In these cases, steel renewal for the internal structures is to be required where the gauged thickness is less than $t_{net}$.

For corrosion addition $t_S$ = 1.0 mm, the thickness for steel renewal is $t_{net}$ and coating or annual gauging may be used for substitution of renewal when gauged thickness is between $t_{net}$ and $t_{net}$ + 0.5 mm.

For coaming structures, the corrosion additions $t_S$ of which are not given in Table 2.20.2.10, steel renewal and coating or annual gauging are to be in accordance with the relevant requirements of CCS.

### 2.20.3 Steel pontoon covers

2.20.3.1 The design load of steel pontoon covers is to comply with the following requirements:

(1) The design load of vertical exposed hatch covers is to be calculated according to Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load $p$ on hatch covers is to be specified by the Owner or designer and included in the loading manual, complying with the following requirements:

① The permissible cargo load $p$ for 'tween deck hatch covers is not to be less than:

$$p = 7.06h \qquad \text{kN/m}^2$$

where: $h$ — the vertical distance, in m, measured from the hatch cover to the underside of hatch cover stiffeners on deck above.

This requirement does not apply to multi-purpose ships of which the 'tween deck hatch covers are used as 'tween deck, see Figure 2.20.3.1(2) of this Section.

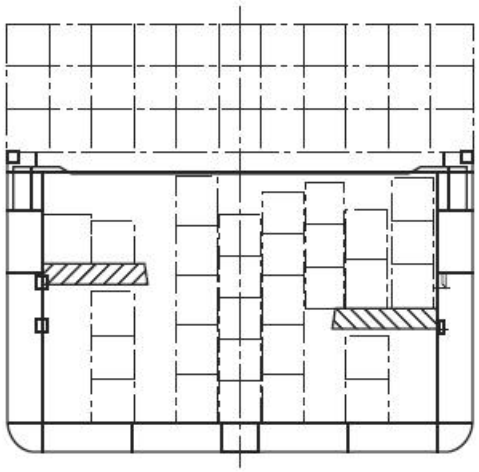


**Figure 2.20.3.1(2)**

② The permissible cargo load $p$ for hatch covers in the accommodation spaces is not to be less than 12.7 kN/m$^2$.

2.20.3.2 The local scantlings of hatch covers are to comply with the following requirements:

(1) The thickness $t$ of the top plating of steel hatch covers is not to be less than that obtained from the following formula:

$$t = 0.01s \quad \text{mm,} \quad \text{but in no case to be less than 6 mm.}$$

where: $s$— spacing of stiffeners, in mm.

(2) The scantlings of stiffeners and girders of steel pontoon covers are to comply with the following requirements:

① Where the uniformly distributed design load of vertical exposed hatch covers is applied, the section modulus $W$ and the section moment of inertia $I$ of stiffeners are not to be less than:

$$W = 7.82Kspl^2 \times 10^{-4} \quad \text{cm}^3$$

$$I = 1.44spl^3 \times 10^{-3} \quad \text{cm}^4$$

where: $p$— vertical weather design load, in kN/m$^2$;

$s$— spacing of stiffeners, in mm;

$l$— span of stiffener, in m;

$K$—material factor.

② Where the uniformly distributed cargo load is applied, the section modulus $W$ and the section moment of inertia $I$ of stiffeners are not to be less than:

$$W = 1.064Kspl^2 \times 10^{-3} \quad \text{cm}^3$$

$$I = 1.8spl^3 \times 10^{-3} \quad \text{cm}^4$$

where: $p$—permissible cargo load, in kN/m$^2$;

$s$—spacing of stiffeners, in mm;

$l$—span of stiffener, in m;

$K$—material factor.

③ Where the ends of stiffeners are effectively bracketed or continuous, the values of section modulus and moment of inertia may be reduced respectively by 33% and 80% than those obtained from ① or ②.

④ The scantlings of girders of steel pontoon covers are to be determined by direct calculations. Where steel pontoon covers are subject to uniformly distributed loading and girders are fitted in one direction only, however, the scantlings of girders may also be determined according to ① and ②.

2.20.3.3 The direct strength calculation of steel pontoon covers is to be in compliance with the requirements of 2.20.2.4 of this Section.

2.20.3.4 Yield strength and deformation criteria of steel hatch covers of steel pontoon covers

The yield strength and deflection of steel pontoon covers are to meet the requirements of Table 2.20.3.4.

**Steel Pontoon Covers** **Table 2.20.3.4**

| Load | Allowable positive stress [$\sigma$] (N/mm$^2$) | Allowable deflection (m) |
|---|---|---|
| Vertical weather design load | 0.70$R_{eH}$ | 0.0049 $l$ |
| Loads other than vertical weather design load | 0.65$R_{eH}$ | 0.0044 $l$ |

2.20.3.5 The buckling strength of steel pontoon covers is to meet the requirements of Table 2.20.3.5(1).

**Buckling Strength Criteria of Steel Pontoon Covers** **Table 2.20.3.5(1)**

| Structural member | | Criteria |
|---|---|---|
| Top panels of hatch covers | Girders fitted in uni-axial direction | The normal stress of top panels in compression of girders is not to exceed 0.8 times the critical buckling stress $\sigma_c$, $\sigma_c$ may be calculated according to 2.20.3.5(1) |
| | Girders fitted in bi-axial directions | Biaxial compressive stress of top panels, when calculated by means of finite plate element model, is to be in accordance with the relevant requirements in 2.20.2.6(1) of this Section |
| Girder webs | | The shear stress of girder web panels is not to exceed 0.8 times the critical shear |

| Structural member | Criteria |
|---|---|
| | buckling stress $\tau_c$, $\tau_c$ may be calculated according 2.20.3.5(3) |
| Stiffeners parallel to girders | The normal stress of attached plating of stiffeners in compression of girders parallel to stiffeners is not to exceed 0.8 times the critical buckling stress $\sigma_c$, $\sigma_c$ may be calculated according to 2.20.3.5(2) |

(1) Hatch cover plating critical stress

The compressive stress $\sigma$ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress $\sigma_{c1}$, to be evaluated as defined below:

$$\sigma_{c1} = \sigma_{E1} \qquad \text{for } \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{c1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \qquad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}$$

where: $R_{eH}$ — yield stress of the material, in N/mm$^2$;

$\sigma_{E1}$ = $3.6E\left(\frac{t}{1000s}\right)^2$, in N/mm$^2$;

$E$ — modulus of elasticity, in N/mm$^2$, = $2.06 \times 10^5$ for steel;

$t$ — net thickness of plate panel, in mm;

$s$ — spacing of secondary stiffeners, in m.

The mean compressive stress $\sigma$ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress $\sigma_{c2}$, to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \qquad \text{for } \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{c2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \qquad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}$$

where: $R_{eH}$ — yield stress of the material, in N/mm$^2$;

$\sigma_{E2}$ = $0.9mE\left(\frac{t}{1000s_s}\right)^2$, in N/mm$^2$;

$m$ = $c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$

$E$ — modulus of elasticity, in N/mm$^2$, = $2.06 \times 10^5$ for steel;

$t$ — net thickness of plate panel, in mm;

$s_s$ — length of the shorter side of the plate panel, in m;

$l_s$ — length of the longer side of the plate panel, in m;

$\psi$ — ratio between smallest and largest compressive stress;

$c$ = 1.3 when plating is stiffened by primary supporting members;

$c$ = 1.21 when plating is stiffened by secondary stiffeners of angle or T type;

$c$ = 1.1 when plating is stiffened by secondary stiffeners of bulb type;

$c$ = 1.05 when plating is stiffened by flat bar.

The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the requirements of 2.20.2.6, Chapter 2 of this PART.

(2) Hatch cover secondary stiffeners critical stress

The compressive stress $\sigma$ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8

times the critical buckling stress $\sigma_{cs}$, to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \qquad \text{for} \quad \sigma_{ES} \le \frac{R_{eH}}{2}$$

$$\sigma_{cs} = R_{eH}\,(1 - \frac{R_{eH}}{4\sigma_{ES}}) \qquad \text{for} \quad \sigma_{ES} > \frac{R_{eH}}{2}$$

where: $R_{eH}$ — yield stress of the material, in N/mm$^2$;

$\sigma_{ES}$ — ideal elastic buckling stress of the secondary stiffener, in N/mm$^2$, = minimum between $\sigma_{E3}$ and $\sigma_{E4}$;

$\sigma_{E3}$ = $\frac{0.001EI_a}{Al^2}$, in N/mm$^2$;

$E$ — modulus of elasticity, in N/mm$^2$, = $2.06 \times 10^5$ for steel;

$I_a$ — moment of inertia of the secondary stiffener, in cm$^4$, including a top flange equal to the spacing of secondary stiffeners;

$A$ — cross-sectional area of the secondary stiffener, in cm$^2$, including a top flange equal to the spacing of secondary stiffeners;

$l$ — span of the secondary stiffener, in m;

$\sigma_{E4}$ = $\frac{\pi^2 EI_w}{10^4 I_p l^2}(m^2 + \frac{K}{m^2})$ + $0.385E\frac{I_t}{I_p}$, N/mm$^2$;

$K$ = $\frac{Cl^4}{\pi^4 EI_w} \times 10^6$;

$m$ — number of half waves, given by Table 2.20.3.5(2);

$I_w$ — sectorial moment of inertia of the secondary stiffener about its connection with the plating, in cm$^6$:

$I_w = \frac{h_w^3 t_w^3}{36} \times 10^{-6}$, for flat bar secondary stiffeners;

$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$, for "Tee" secondary stiffeners;

$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w] \times 10^{-6}$, for angles and bulb secondary stiffeners;

$I_p$ — polar moment of inertia of the secondary stiffener about its connection with the plating, in cm$^4$:

$I_p = \frac{h_w^3 t_w}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$I_p = (\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f) \times 10^{-4}$, for flanged secondary stiffeners;

$I_t$ — St Venant's moment of inertia of the secondary stiffener without top flange, in cm$^4$:

$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$I_t = \frac{1}{3}[h_w t_w^3 + b_f t_f^3(1 - 0.63\frac{t_f}{b_f})] \times 10^{-4}$, for flanged secondary stiffeners;

$h_w$ — web height of the secondary stiffener, in mm;

$t_w$ — web net thickness of the secondary stiffener, in mm;

$b_f$ — width of the secondary stiffener bottom flange, in mm;

$t_f$ — net thickness of the secondary stiffener bottom flange, in mm;

$s$ — spacing of secondary stiffeners, in m;

$C$ — spring stiffness exerted by the hatch cover top plating, calculated by the following formula:

$$C = \frac{k_p E t_p^3}{3s(1+\frac{1.33 k_p h_w t_p^3}{1000 s t_w^3})} \times 10^{-3};$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged secondary stiffeners, $k_p$ need not be taken as less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{E1}};$$

$\sigma$ —normal stress of the attached plate of the wing plate of the primary supporting member;

$\sigma_{E1}$ — as given in 2.20.3.5(1);

$t_p$ — net thickness of the hatch cover plate panel, in mm.

**Number of Half Waves ($m$ value)** **Table 2.20.3.5(2)**

| $K$ | $0 < K \leq 4$ | $4 < K \leq 36$ | $36 < K \leq 144$ | $(m-1)^2 m < K \leq m^2(m+1)^2$ |
|---|---|---|---|---|
| $m$ | 1 | 2 | 3 | $m$ |

(3) Web panels of hatch cover primary supporting members critical stress

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress $\tau$ in the hatch cover primary supporting member web panels is not to exceed 0.8 times the critical buckling stress $\tau_c$, to be evaluated as defined below:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_F}{2}$$

$$\tau_c = \tau_F (1 - \frac{\tau_F}{4\tau_E}) \quad \text{for } \tau_E > \frac{\tau_F}{2}$$

where: $\tau_F = \frac{R_{eH}}{\sqrt{3}}$ N/mm$^2$;

$R_{eH}$ — yield stress of the material, in N/mm$^2$;

$$\tau_E = 0.9 k_t E \left[\frac{t_{pr,n}}{1000 d}\right]^2 \text{ N/mm}^2;$$

$E$ — modulus of elasticity, in N/mm$^2$, = $2.06 \times 10^5$ for steel;

$t_{pr,\,n}$ — net thickness of primary supporting member, in mm;

$$k_t = 5.35 + 4.0\left(\frac{d}{a}\right)^2;$$

$a$ — greater dimension of web panel of primary supporting member, in m;

$d$ — smaller dimension of web panel of primary supporting member, in m.

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension $d$ is to be taken for the determination of the stress $\tau_c$. In such a case, the average shear stress $\tau$ between the values calculated at the ends of this panel is to be considered.

2.20.3.6 Steel pontoon covers are to be provided with tarpaulins and securing devices in accordance with the following requirements:

(1) At least two layers of tarpaulin in good condition are to be provided for each hatchway in exposed freeboard and superstructure decks.

(2) Tarpaulins are to be free from jute, and the minimum weight in unit area of the material before treatment is to be:

0.65 kg/mm$^2$, if the material is tarred;

0.65 kg/mm$^2$, if the material is chemically dressed;

0.55 kg/mm$^2$, if the material is dressed with black oil.

(3) Cleats are to be welded to the hatch coamings or the horizontal stiffeners, and the cleats are to be so set as to fit the taper of the wedges. The width of cleats is not to be less than 65 mm, and the cleats are to be spaced not more than 600 mm from centre to centre. The first and last cleats along each side or end are to be arranged not more than 150 mm from the hatch covers.

(4) Wedges are to be of tough wood. They are to have a taper of not more than 1 in 6 and are not to be less than 13 mm in thickness at the point.

(5) For all hatchways situated in exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

(6) For all hatchways situated in other exposed positions, ring bolts or other fittings for lashings are to be provided.

2.20.3.7 The hatch coamings of steel pontoon covers are to comply with the following requirements:

(1) Construction of exposed hatch coamings

① The thickness $t$ of hatch coamings is not to be less than that obtained from the following formula:

$$t = 0.05L + 6.5 \quad \text{mm}$$

where: $L$— length of ship, in m, need not be greater than 90 m.

② Coamings of 600 mm or more in height are to be stiffened on their upper edges or at about 250 mm below the upper edge by a horizontal bulb flat or equivalent strength member. The web depth of the horizontal bulb flat is not to be less than 180 mm, and an additional support is to be afforded by fitting vertical stays or brackets from the bulb flat to the deck at intervals of not more than 3 m. The web depth of the stiffeners or brackets is to be not

less than that of the horizontal bulb flat and they are to be flanged or fitted with a face plate. Where the coamings are more than 900 mm in height, the spacing of the above-mentioned stays or brackets is to be suitably reduced. Where the coamings are equal to or more than 1,200 mm in height, an additional horizontal bulb flat or equivalent strength member is to be fitted in way of half height of the coaming. Where the coamings are subject to loaded containers, the hatch coamings and their supporting members are to be strengthened correspondingly.

③ Where no face plate is fitted, the upper edges of coamings are to be stiffened by half round bars or other rolled bars to ensure the rigidity of coamings and the smoothness of their upper edges.

④ Where the deck plating does not extend inside the coamings, the coamings at the corners of hatchways are to be rounded. For openings within 0.5*L* amidships, the radius of the rounded corner is to comply with the requirements of 2.4.4 of this Chapter.

If the deck plating extends inside the coamings, the coamings at the corners of hatchways may be square provided that the corners of deck openings are in compliance with the requirements of 2.4.4 of this Chapter and that the longitudinal coamings at hatch corners are extended in the form of a tapered bracket.

⑤ Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deckhouse or masthouse, unless upon calculation it shows that the hatch coamings may be used as longitudinal strength members of the hull.

⑥ Where the exposed hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

(2) Where the 'tween deck hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

### 2.20.4 Hatch covers with portable beams

2.20.4.1 The design load of hatch covers with portable beams is to comply with the following requirements:

(1) The vertical weather design load of exposed hatch covers is to comply with Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load on hatch covers is to comply with the requirements of 2.20.3.1(2) of this Section.

2.20.4.2 Hatch covers with portable beams are to be in compliance with the following requirements:

(1) Hatch covers with portable beams, where the cover is made of steel, are to meet the requirements of 2.20.3.2(1) of this Section; where the cover is made of wood, the thickness $t$ is not to be less than that obtained from the following formula:

$$t = 40S \quad \text{mm, but in no case to be less than 60 mm}$$

where: $S$— spacing of portable hatch beams, in m.

Where the design load exceeds 18.4 kN/m$^2$, the thickness of wood covers is to be increased in direct proportion to the load.

Both ends of wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 3 mm thick, efficiently secured.

(2) Where the vertical design load is applied, the exposed hatch covers with portable beams are to comply with the following requirements:

① The section modulus $W$ and the section moment of inertia $I$ of the portable beams are not to be less than:

$$W = 0.782\ KSpl^2 \quad \text{cm}^3$$
$$I = 1.44\ Spl^3 \quad \text{cm}^4$$

where:

$p$ — vertical weather design load, in kN/m$^2$, to be calculated according to 2.20.4.1 of this Section;

$S$ — spacing of portable beams, in m;

$l$ — span of portable beam, in m;

$K$ — material factor.

② The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.

③ The portable beams are to be stiffened at their upper and lower edges by continuous face plates. The width of the upper face plate is to be sufficient to provide a bearing surface of not less than 65 mm for hatch covers, and a vertical flat bar with a height of 50 mm is to be arranged on the upper face plate.

④ Carriers or sockets are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is at least to be 75 mm.

⑤ The section modulus $W$ and the section moment of inertia $I$ of stiffeners of steel covers are not to be less than:

$$W = 0.664Kspl^2 \quad \text{cm}^3$$
$$I = 1.13spl^3 \quad \text{cm}^4$$

where:

$p$ — vertical weather design load, in kN/m$^2$, to be calculated according to 2.20.4.1 of this Section;

$l$ — span of stiffener, in m;

$s$ — spacing of stiffeners, in m;

$K$ — material factor.

(3) Where the uniformly distributed cargo load is applied, the hatch covers with portable beams are to comply with the following requirements:

① The section modulus $W$ and the section moment of inertia $I$ of portable beams are not to be less than:

$$W = 1.064KSpl^2 \quad \text{cm}^3$$
$$I = 1.8Spl^3 \quad \text{cm}^4$$

where:

$p$ — permissible cargo load, in kN/m$^2$;

$S$ — spacing of portable beams, in m;

$l$ — span of portable beam, in m;

$K$ — material factor.

② Portable beams are also to comply with the requirements of 2.20.4.2(2)② to ④.

③ The section modulus $W$ and the section moment of inertia $I$ of portable beams are not to be less than:

$$W=1.064Kspl^2 \quad cm^3$$
$$I=1.8spl^3 \quad cm^4$$

where:

$p$ — permissible cargo load, in kN/m$^2$;

$l$ — span of portable beam, in m;

$s$ — spacing of portable beams, in m;

$K$ — material factor.

(4) The scantling of stiffeners and girders with a variable cross-section for hatch covers with portable beams are to comply with the requirements of 2.20.3.2(3) of this Section.

2.20.4.3 The direct strength calculation of hatch covers with portable beams is to comply with the requirements of 2.20.2.4 of this Section.

2.20.4.4 The yield strength and deformation of hatch covers with portable beams is to comply with the requirements of 2.20.3.4 of this Section.

2.20.4.5 The buckling strength of hatch covers with portable beams is to comply with the requirements of 2.20.3.5 of this Section.

2.20.4.6 The closing appliances of hatch covers with portable beams are to comply with the requirements of 2.20.3.6 of this Section.

2.20.4.7 The hatch coamings of hatch covers with portable beams are to comply with the requirements of 2.20.3.7 of this Section.

### 2.20.5 Miscellaneous openings

2.20.5.1 Miscellaneous openings are to comply with the requirements of 1.12.7 of Chapter 1 of this PART.

2.20.5.2 Small hatchways on exposed decks are also to comply with the following requirements:

(1) The height of coamings of small hatchways is to comply with the requirements of 2.20.1.8 of this Section. The thickness of the coamings is not to be less than the minimum thickness as required in this Chapter for the deck inside the line of openings for that position, or 11 mm, whichever is the lesser;

(2) Small hatchways are to be provided with steel weathertight hatch covers and reliable securing devices. The means of securing are to be such that weathertightness can be maintained in any condition. The thickness of the hatch covers is not to be less than the minimum thickness required by this Chapter for the deck inside the line of openings for that position, or 8 mm, whichever is the lesser;

(3) Strength and securing of small hatches on the exposed fore deck are also to comply with the relevant requirements of Section 7, Chapter 1 of this PART.

## Section 21 VEHICLE DECKS

### 2.21.1 General requirements

2.21.1.1 Where wheeled vehicles are to be stowed on the deck or used for cargo handling, the scantlings of the deck or hatch covers are to comply with the relevant requirements in this PART and in addition, are to be checked for strength in accordance with the requirements of this Section.

2.21.1.2 Where wheeled vehicles are to be stowed on the inner bottom or used for cargo handling, the strength of inner bottom plating in way may also be checked by reference to the requirements of this Section.

### 2.21.2 Deck plating

2.21.2.1 The thickness of deck plating is to comply with the following requirements:

(1) The thickness $t$ of deck plating is not to be less than that obtained from the following formula:

$$t = CJ\sqrt{PK} + 1.5 \quad \text{mm}$$

where: $P$ — load, in $t$, on the tyre print. Two closely spaced wheels may be regarded as a combined wheel print and the sum of loads on both tyre prints is to be taken;

$K$ — material factor;

$C, J$ — coefficients, to be calculated as follows:

For $0.5 \leq \frac{u}{v} < 1$:

$$J = 0.73(0.85 - \frac{u}{v}) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - (0.099\frac{v}{s} + 0.013)(2.5 - \frac{l}{s})$$

For $1 \leq \frac{u}{v} < 2$:

$$J = 0.51(0.79 - \frac{u}{v}) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - (0.156\frac{v}{s} + 0.009)(2.5 - \frac{l}{s})$$

For $2 \leq \frac{u}{v} < 3$:

$$J = 0.4(0.66 - \frac{u}{v}) + \frac{4.30}{\frac{v}{s} + 0.57}$$

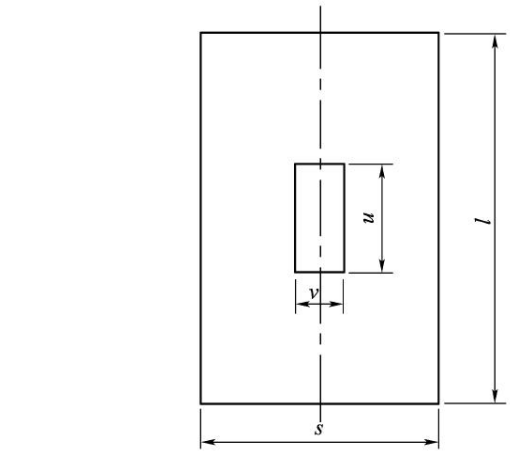
$$C = 1 - (0.196\frac{v}{s} + 0.013)(2.5 - \frac{l}{s})$$

where: $\frac{u}{v}$ — aspect ratio of tyre print, see Figure 2.21.2.1(1). For 2 tyre prints on one plate panel, see Figure 2.21.2.1(2), $u' = 2u$; where $\frac{u'}{v} \geq 3$, calculating by $u_1 = v_1 = \sqrt{u'v}$;

$l$ — span of frames, in m;

$s$ — spacing of frames, in m;

when $l/s > 2.5$, to be taken as 2.5.



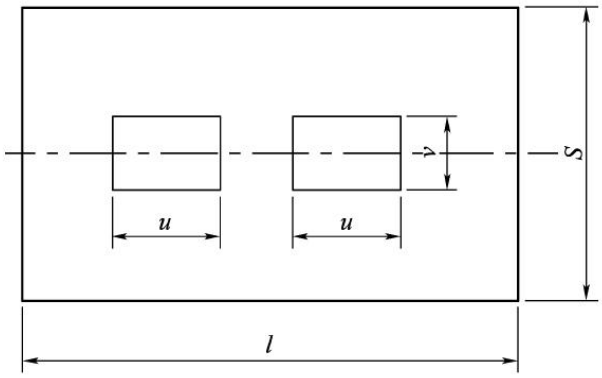




**Figure 2.21.2.1(1)** **Figure 2.21.2.1(2)**

(2) Where forklift trucks are to be used for cargo handling on decks and no data for tyre print and deadweight, etc., are available, the thickness of deck plating may be obtained in accordance with the following formula:

$$\frac{s}{t} \leq \frac{111}{P+1} + 27$$

where: $t$ — thickness of deck plating, in mm;

$s$ — spacing of deck longitudinals or beams, in mm;

$P$ — cargo weight lifted by the forklift truck, in t.

(3) Where wheeled vehicles are to be stowed or used on insulated decks, attention is to be paid to the effect on the insulation coating due to deck deformation when the permissible loading of decks is determined based on the thickness of deck plating.

2.21.2.2 The section modulus of deck beams and longitudinals are to comply with the following requirements:

(1) Where forklift trucks are to be used for cargo handling on cargo deck, the section modulus $W$ of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.375J_1Pl + 1.25J_2hsl^2)K \quad \text{cm}^3$$

where: $P$ — total weight of forklift truck, in t;

$h$ — design head on the deck, in m, see 2.8.1.1 of this Chapter;

$s$ — spacing of frames, in m;

$l$ — span of frames, in m;

$K$ — material factor;

$J_1$, $J_2$ — coefficients, to be taken according to Table 2.21.2.2.

**Coefficients $J_1$ and $J_2$** **Table 2.21.2.2**

| $J$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 and over |
|---|---|---|---|---|---|
| $J_1$ | 15.4 | 14.6 | 13.35 | 11.8 | 10.1 |
| $J_2$ | 1.89 | 1.85 | 1.73 | 1.55 | 1.30 |

Note: $J$ = wheel spacing/span of frame, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

(2) Where decks are permanently intended for the carriage of vehicles, the section modulus $W$ of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.536J_1Pl + 1.25J_2shl^2)K \quad \text{cm}^3$$

where: $P$ — load on one axle, in t, i.e. total weight of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, $P$ is to be taken as the maximum axle load;

$h$ — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter, but $h$ need not be more than 2.5 m;

$s$ — spacing of frames, in m;

$l$ — span of frames, in m;

$K$ — material factor;

$J_1$, $J_2$ — coefficients, to be taken according to Table 2.21.2.2.

(3) In addition to the above-mentioned requirements, the strength of deck beams or lonitudinals is to be checked according to the following requirements: the allowable bending stress is not to exceed $104/K$, in N/mm² if it is assumed that both ends of beams or longitudinals are fixed rigidly and that the beam is only subjected to the concentrated load of wheels.

2.21.2.3 The section modulus of deck transverses or girders is to comply with the following requirements:

(1) Where the deck transverses or girders are subject to uniformly distributed loading, the section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 4.75bhl^2K \quad \text{cm}^3$$

where: $b$ — spacing of transverses or girders, in m;

$l$ — span of transverse or girder, in m;

$h$ — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter;

$K$ — material factor.

(2) Where the deck girders or transverses are subject to concentrated loads, with or without the addition of uniformly distributed load, the section modulus is to be determined by calculations. During the calculation, 100% end fixity is to be assumed, and the permissible bending stress is to be taken as $118/K$, in N/mm².

### 2.21.3 Hatch covers

2.21.3.1 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the thickness of hatch cover plating is to comply with the provisions in 2.21.2.1 of this Section.

2.21.3.2 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the section modulus $W$ of hatch cover stiffeners is not to be less than that obtained from the following formula:

$$W = (J_3Pl + 1.67J_4shl^2)K \quad \text{cm}^3$$

where: $P$ — load on one axle, in t, see 2.21.2.2 of this Section;

$h$ — design head on the hatch cover, in m; see 2.21.2.2 of this Section; $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m;

$K$ — material factor;

$J_3$, $J_4$ — coefficients, to be taken according to Table 2.21.3.2.

**Coefficients $J_3$ and $J_4$** **Table 2.21.3.2**

| $J$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| $J_3$ | 11.96 | 10.69 | 9.58 | 8.46 | 7.46 | 6.51 | 5.55 | 4.23 | 2.38 |
| $J_4$ | 2.32 | 1.89 | 1.55 | 1.28 | 1.07 | 0.91 | 0.73 | 0.36 | 0.11 |

Note: $J$ = wheel spacing/span of stiffeners, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

# Section 22 STRENGTHENED FOR HEAVY CARGOES

### 2.22.1 General requirements

2.22.1.1 This Section applies to dry cargo ships with strengthened for heavy cargoes.

2.22.1.2 Ships of loading rate γ not greater than 0.833m$^3$/t (see 1.1.2.15 of Chapter 1) are to comply with the requirements of this Section, except when loaded by steel coils on a wooden support.

2.22.1.3 Special considerations are to be given to strengthening requirements where the inner bottom plating of the cargo hold is loaded by bulky cargo or bearing concentrated load.

### 2.22.2 Requirements for hull structures

2.22.2.1 The strength deck and bottom in way of cargo holds are to be framed longitudinally, and the ship is to be provided with a double bottom within the region of cargo spaces.

### 2.22.3 Strengthening of bottom framing

2.22.3.1 The plate floors are generally to be spaced not more than 2.5 m apart, and the thickness of the floors is not to be less than that required in 2.6.11.2 of this Chapter.

2.22.3.2 The bottom girders are generally to be spaced not more than 3.6 m apart, and the thickness of side girders is not to be less than that required in 2.6.10.2 of this Chapter.

2.22.3.3 The thickness of watertight or oiltight floors is to comply with the requirements of 2.6.11.2 of this Chapter.

2.22.3.4 The thickness $t$ of inner bottom plating is not to be less than that obtained from the following formulae:

$$t = (0.04L + 5s + 1.1)\sqrt{K} + 5 \quad \text{mm}$$

$$t = 4.65s\sqrt{\frac{HK}{\gamma}} \quad \text{mm}$$

where: $L$ — length of ship, in m, $L$ need not be taken greater than 400 m;

$s$ — spacing of inner bottom longitudinals, in m;

$\gamma$ — stowage rate, in m³/t, but not to be greater than 0.833;

$H$ — vertical distance, in m, measured from the inner bottom plating to deck at side amidships;

$K$ — material factor.

2.22.3.5 The section modulus $W$ of inner bottom longitudinals is not to be less than 85% of that of bottom longitudinals as required in 2.6.12.2 of this Chapter, nor to be less than that obtained from the following formula:

$$W = \frac{8.5}{\gamma} Hsl^2 K \quad \text{cm}^3$$

where: $\gamma$, $H$ and $s$ — same as defined in 2.22.3.4 of this Section;

$l$ — span of inner bottom longitudinal, in m;

$K$— material factor.

2.22.3.6 Where vertical stays are fitted in way of the mid-span of inner bottom longitudinals and the inner bottom longitudinals are subject to uniformly distributed loading, the scantlings of bottom longitudinals and stays may be determined by direct calculations.

2.22.3.7 The construction of the duct keel is to comply with the requirements of 2.6.3 of this Chapter. But the section modulus $W$ of the inner bottom stiffening members is not to be less than the values derived from 2.22.3.5 of this Section, and in this case $s$ is the spacing of the stiffening members, in m, and $l$ is the span of stiffening members, in m.

# Section 23 ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF CARGO TANK STRUCTURE

### 2.23.1 General requirements

2.23.1.1 This Section applies to ships carrying liquefied gases in bulk, ships carrying dangerous liquid chemicals having a temperature higher than 80℃ at atmospheric pressure in bulk, oil tankers and asphalt carriers, and contains specific requirements for cargo tank thermal stress calculation as required in Chapter 10, PART EIGHT of the Rules, Chapter A4 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk, Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, and other relevant rules of CCS.

2.23.1.2 Without approval, the following two loading modes are not to be used:

(1) cargoes of different temperatures and natures are carried simultaneously in adjacent tanks or in the cargo tank area;

(2) liquid cargo and ballast water of high (low) temperature are carried simultaneously in cargo tanks and adjacent ballast tanks.

2.23.1.3 In this Section, the thermal stress calculation for cargo tanks include two steps which are to be performed in sequence. At step 1, the distribution of temperature field of cargo tanks and associated structures is to be obtained through heat transferring analysis with the given

temperatures of hot/cold sources of liquid cargo and the given ambient temperatures. Step 2 is to use the distribution of temperature field so obtained as input condition for thermal analysis, so as to obtain the thermal-expansion-induced thermal stress of any structure in the temperature field due to temperature difference.

2.23.1.4 The heat transferring calculation in this Section is based on an assumed steady state heat transferring in three-dimensional space, no change of material parameters and boundary conditions is made in conjunction with any temperature change in the analysis of linear heat transferring, and only the effects of transferring through structures and insulation are considered.

2.23.1.5 The thermal calculation in this Section is based on the assumption of a "sequentially coupled heat-structure (sequentially coupled problem)", i.e., the effects of changes in the temperature field on the machinery field are considered without taking account of the effects of the latter on the former. Moreover, the high temperature creeping effects of structures are not considered.

2.23.1.6 In calculation, it is assumed that heat is transferred between hull structural members by conduction, and that heat exchange between air and hull structural members exposed to it is natural convection only.

2.23.1.7 In heat transferring calculation and thermal stress analysis, recognized finite element thermal analysis programs and finite element structural analysis programs are to be used.

2.23.1.8 Methods or assumptions other than those specified in the Rules are to be used in calculation are to be subject to approval.

### 2.23.2 Plans and documents

2.23.2.1 In addition to calculations as generally required by relevant documents for direct finite element structural calculation, the following heat transferring calculation and thermal stress analysis documents together with associated drawings and documents are to be submitted:

(1) Arrangement of insulation layers and details of their connection;

(2) Thermal parameters of insulation layers (coefficient of thermal conductivity, etc.);

(3) Heat balance calculation and analysis report, including the following:

a. maximum design temperature of liquid cargo to be carried (the temperature indicated in class notation);
b. design target values of external surface temperature of steel plating of inner side, inner bottom and deck, if any;
c. lowest/highest ambient temperature (atmosphere and seawater) for intended operating route;
d. distribution of temperature field under consideration.

(4) Thermal stress calculation report: thermal stress calculation based on the distribution of temperature field as obtained according to (3) and performed according to this Section, including check of resultant stresses for combinations of thermal stress with corresponding sea conditions and loading conditions.

### 2.23.3 Model for analysis

2.23.3.1 Scope of model: For integral tanks, it is to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. If necessary (temperature gradient is large), modeling of the fore end area of the foremost cargo tank and that of the aft end area of the aftermost cargo tank are

to be considered. For independent tanks, at least the entire tank structure is to be taken. For the effects of temperature on the supporting structure of cargo tanks and on the hull, see the relevant requirements of Appendix 1, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For heat transferring analysis, the model is to cover all contributing heat insulation materials and structures, except that stainless liner may be neglected; for thermal stress analysis, the model is merely a structural one.

2.23.3.2 Structural elements: The principled requirements for modeling in respect to types of elements and meshing, etc., are as given in Section 5, Chapter 1 of this PART.

2.23.3.3 Insulation elements: For rock wool thermal insulation, the elements are generally of solid-element type, thickness is taken as that of the insulation layer (excluding stainless liner), and other principles for modeling, e.g. element type selection and meshing, are similar to those for structures. However, simplification is allowed, as appropriate, in way of complex intersection of certain structures (insulation), e.g. connection of a longitudinal or transverse corrugated bulkhead with upper stool.

2.23.3.4 Boundary conditions for heat transferring analysis:

(1) The thermal transferring analysis for the determination of steel grades required for structural materials used at low temperatures is to be in accordance with the following requirements:

a. For ships carrying dangerous chemicals in bulk, to which CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk. For ships carrying liquefied gases in bulk, to which CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

b. For ships not covered by a. above, the boundary conditions regarding external atmospheric temperature and seawater temperature are as follows:
portions of hull below draught line – the defined surface temperature is the lowest temperature in water and if icing is possible for the intended operating route, this temperature is to be taken as 0°C;
portions of hull above draught line – the defined surface temperature is the possibly lowest atmospheric temperature for the intended operating route, e.g. -20°C.

(2) In respect to the determination of maximum thermal stress, the temperature load condition applied as input for the thermal analysis is to be the maximum difference between the liquid cargo temperature and the ambient temperature for the intended operating route.

(3) For the side of cargo tank insulation or bare structural shell which is in direct contact with liquid cargo, the defined surface temperature is the highest stable temperature of liquid cargo being carried.

(4) For the space within double bottom and double side skin, the ambient temperature may be directly taken a little higher than the external temperature, and the assumed convective heat transfer between air and steel plating as mentioned above (heat transferring by air is assumed to be little) is defined in respect to external surfaces of inner side shell and inner bottom (the surfaces

not exposed to liquid cargo). Alternatively, this space may be taken as a three-dimensional finite element model of air elements and incorporated into the finite element heat transferring model. The heat transferring calculation is performed according to the assumption of 2.23.1.6, without taking account of the heat transferring by air. Where there are special requirements for the highest temperature criterion regarding periphery of cargo tanks, the surface temperature is to be defined as so required.

(5) The external surface temperature of the independent tank structure is to be defined according to the above requirements, as applicable.

(6) The gas temperature in cargo tanks in the half-loaded condition may be assumed as the liquid cargo temperature, and the boundary conditions for heat convection of gas are to be used to simulate the effects of gas on structure.

2.23.3.5 In thermal analysis, the structural boundary conditions for the integral tank model are to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. For independent tanks, the model structural boundary conditions are to be taken as those for the loading conditions corresponding to temperature loads. In addition, restraint of linear displacement $\delta_x$ in the direction of ship's length is to be released at a certain end (e.g. end B) of section model for the structural boundary condition of above model.

### 2.23.4 Thermal calculation and loading conditions

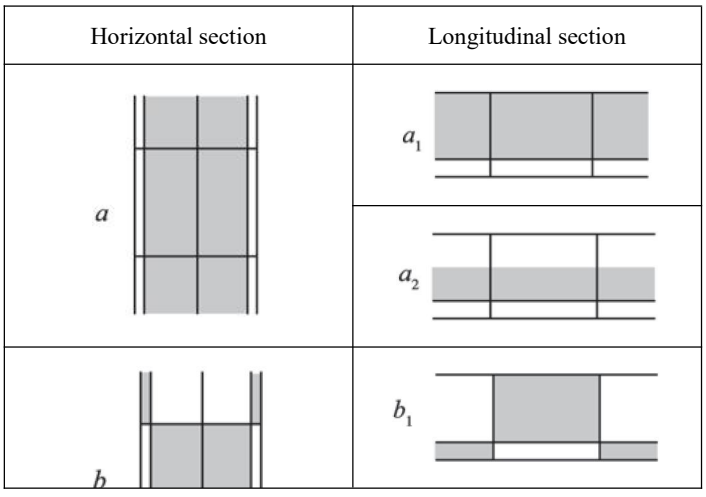
2.23.4.1 The distribution values of the three-dimensional temperature field obtained from heat transferring analysis are to be used as temperature loads in structural strength calculation. For tankers as stipulated in the Rules, where independent tanks are fitted, temperature loads in the full load condition are to be calculated; where integral tanks are fitted, the load conditions are to be as shown in Figure 2.23.4.1, and the following are to be complied with:

(a) — only sagging mode is considered;

(b), (c) — sagging and hogging modes are considered respectively.

And for (a), (b) and (c), both full and half load conditions in the above modes are to be considered. The half load condition means the loading height of liquid cargo is half the height of tank.

Where any loading condition specified in the loading manual or occurring in service is worse than the above conditions under consideration, the temperature load calculated to such loading condition is to be included. For cargo tanks of other ship types, temperature loads in relevant loading conditions are to be calculated in accordance with the requirements of the applicable rules.



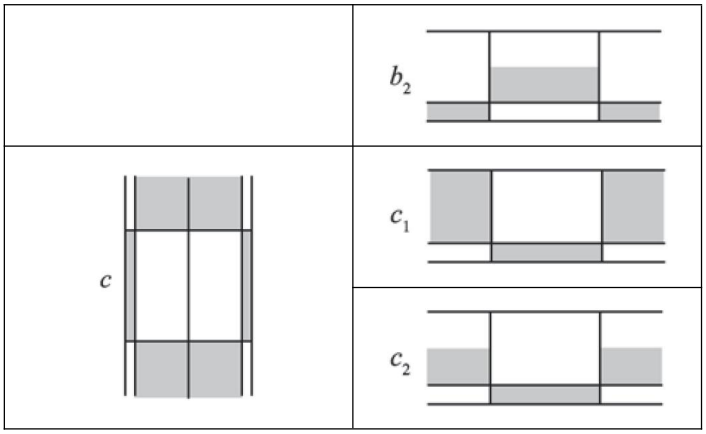



**Figure 2.23.4.1**

2.23.4.2 The temperature loads as calculated above are to be applied to the model of each corresponding loading condition. The calculation and application of routine loading conditions are to follow the applicable requirements in Appendix 1, Chapter 5 of this PART, Appendix 1 and Appendix 2, Chapter 4 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and other relevant documents or routine practice.

2.23.4.3 Where only longitudinal tension and compression stresses less than $42/K$ N/mm$^2$ ($K$ being material factor) are applied in regard to thermal stresses induced by temperature loads, the longitudinal bending moment of hull girder may not to be applied to both ends of the model under consideration, subject to agreement.

2.23.4.4 The heat conduction coefficient and linear expansion coefficient of steel as well as the convective heat exchange coefficient of air are to be provided by designer. For asphalt carriers during preliminary design, reference may be made as follows:

Heat conduction coefficient of carbon steel: 60.6 W/(m·K) – for heat transferring calculation (thermal analysis);

Linear expansion coefficient of carbon steel: $11\times10^{-6}$(1/K) – for heat stress calculation (structural analysis);

Convective heat exchange coefficient of air: 11.6 W/(m$^2$·K) – for heat transferring calculation (thermal analysis). Where the length of the finite element model is measured in mm, the value taken is to be multiplied by $10^{-6}$.

The heat conduction coefficient for insulation material is to be taken according to the actual design.

### 2.23.5 Strength criteria

2.23.5.1 For an integral tank model, the criteria are as given in Appendix 1, Chapter 5 of this PART; for hull portion of an independent tank model, the criteria are as given in Appendix 1 and Appendix 2 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; for construction materials of independent tanks of petroleum asphalt carriers, the criteria are as given in Section 2 of Chapter 10, PART EIGHT of the CCS Rules for Classification of Sea-going Steel Ships.

2.23.5.2 Where wave loads are obtained by direct calculation on the basis of dynamic loading, the permissible stress taken according to 2.23.5.1 may be multiplied by 1.1 and the minimum buckling safety factor may be multiplied by 0.9.

2.23.5.3 For a finite element model, for which the longitudinal hull girder bending moment is not taken into account, the permissible stress is to be adjusted as follows on the basis of Appendix 1, Chapter 5 of this PART, without any change to other requirements:

$[\sigma_e] = 175/K$ for all plating

$[\sigma_l] = 110/K$ for longitudinal plating

$[\tau] = 83/K$ for longitudinal girders

$[\tau] = 93/K$ for transverse members (including floors, transverse bulkheads)

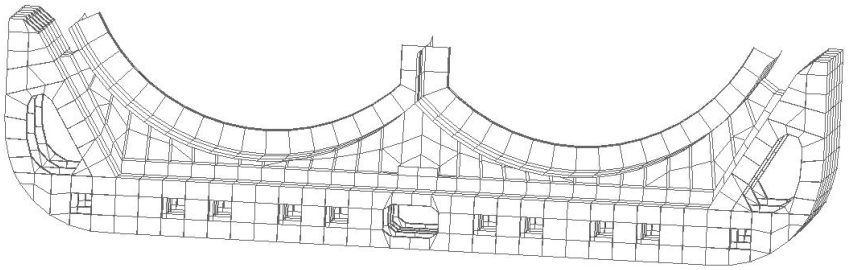
where: $K$ — material factor.

### 2.23.6 Inner liner or membrane

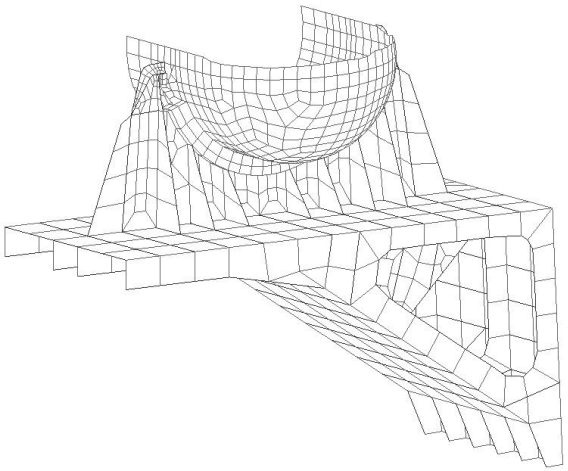
2.23.6.1 For an integral tank model, consideration is to be given to using suitable elastic joints and slightly movable riveting means to eliminate or reduce its inner stressing and deformation due to temperature-induced expansion or contraction of the inner liner or membrane, ensuring that the thermal stress of the inner liner or membrane will not exceed the permissible value and that the deformation will not cause any damage to the function of insulation layers.

### 2.23.7 Analysis of temperature field for supporting structures of independent tank

2.23.7.1 The finite element model for analysis of temperature field includes supporting structure and its connected hull structure as well as independent tank structure.



(1) Finite element model for analysis of temperature filed of supporting structure of independent tank



(2) Finite element model for analysis of temperature field of supporting structure of deck tank

**Figure 2.24.7.1 Finite Element Model of Supporting Structure of Independent Tank**

2.23.7.2 The types of elements and meshing for structural finite element model are to meet the relevant requirements of Section 5, Chapter 1 of this PART of the Rules.

2.23.7.3 Geometry element, generally hexahegdron element is to be used for laminiated wood structure.

2.23.7.4 The longitudinal range of model is to include spacing of each web frame before or after supporting structure, the transverse range is to be taken as the width of ship (for deck tank, to be taken as the overall width of supporting structure), the vertical range is to be taken as the distance from the bottom of ship to the top of supporting structure (for deck tank, to be taken as the distance from deck structure to the top of supporting structure).

2.23.7.5 Boundary conditions for heat transferring analysis of hull structure connected with supporing structure are to be in accordance with the 2.23.3.4 of this Section, those for independent tank connected with supporting structure are to be taken as the temperature of liquid cargo, and those for supporting structure exposed in air are to be taken as the conditions for convective heat transfer, see Figure 2.23.7.5.

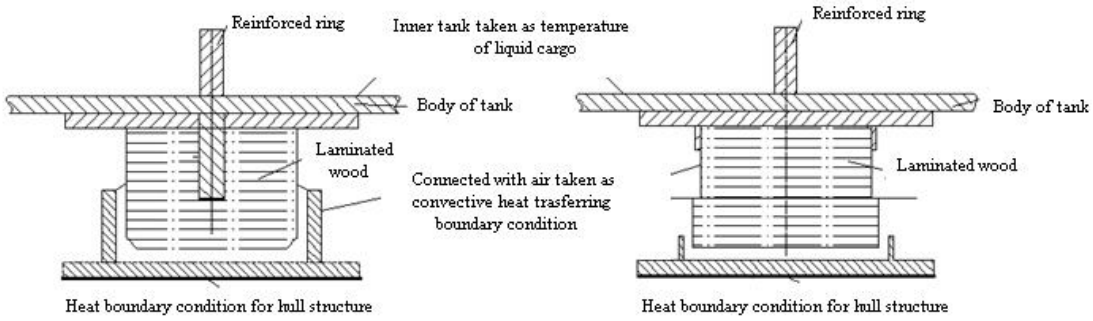



**Figure 2.23.7.5 Diagram of Boundary Conditions for Analysis of Temperature Field of Supporting Structures**

2.23.7.6 For material properties and air convection coefficient of model, see the relevant requirements of 2.23.4.4 of this Section.

2.23.7.7 The analysis of temperature field is to at least include the ambient temperature conditions specified in Chapter 4, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

# Section 24 STRUCTURAL STRENGTHENING LOADED BY STEEL COILS ON A WOODEN SUPPORT

### 2.24.1 General requirements

2.24.1.1 The thickness of inner bottom plating, bilge hopper sloping plate and inner hull plating up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating as well as section modulus and shear area of stiffeners for ships intended to carry steel coils are to comply with the requirements of this Section.

2.24.1.2 The provision is determined based on the assumption of Figure 2.24.1.2 as the standard means of securing steel coils on the dunnage.

2.24.1.3 All steel coils are presumed to be of the same characters.

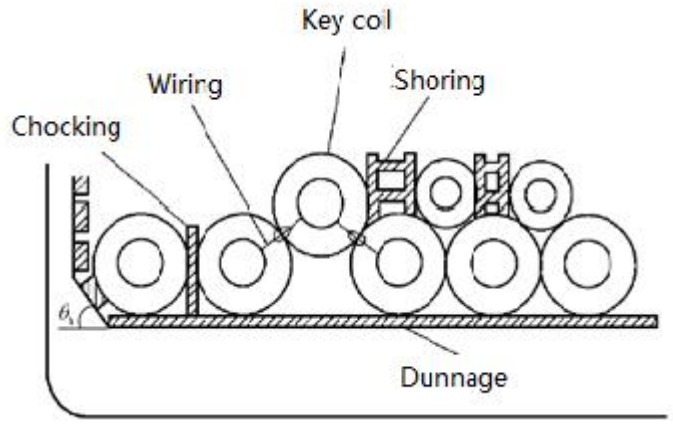



**Figure 2.24.1.2 Inner Bottom Loaded by Steel Coils**

### 2.24.2 Accelerations

2.24.2.1 In order to calculate the accelerations, the following coordinates are to be used for the transverse and vertical positions of calculated point:

$$y_{G-SC} = \begin{cases} B_h/4 & \text{for port} \\ -B_h/4 & \text{for starboard} \end{cases}$$

$$z_{G-SC} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{SC}}{2}$$

where: $B_h$ — breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull;

$d_{sc}$ — diameter of steel coils, in m;

$h_{DB}$ — depth of double bottom, in m.

Vertical acceleration $a_v$, in m/s$^2$, are to be calculated by the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART and tangential acceleration $a_R$ due to roll, in m/s$^2$, is to be calculated by the following formula:

$$a_R = \varphi_m \left(\frac{2\pi}{T_R}\right)^2 \sqrt{{y_{G-SC}}^2 + R^2} \qquad \text{m/s}^2$$

where: $\varphi_m$, maximum angle of roll, $T_R$, roll period — see the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART**;**

$$R = z_{G-SC} - \min\left(\frac{D}{4} + \frac{d}{2}, \frac{D}{2}\right)$$

where: $d$ — draught, in m.

### 2.24.3 Inner bottom plating

2.24.3.1 The thickness of plating of longitudinally framed inner bottom is not to be less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{\left(g + 0.5a_v\right)F_{SC}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: $K_1$— coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7slK_2 - 0.73s^2K_2^2 - \left(l - l'\right)^2}{2l'\left(2s + 2lK_2\right)}}$$

$t_c$ — corrosion addition, in mm, generally taken 2.5 mm, to be taken 5 mm where the cargo holds are designed for loading/unloading by grabs;

$a_v$ — vertical acceleration, in m/s$^2$, calculated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART;

$g$ — acceleration due to gravity, $g$ = 9.81 m/s$^2$;

$F_{SC}$— equivalent mass of steel coils, in kg, taken equal to:

$$F_{SC} = K_S\frac{W_{SC}n_1n_2}{n_3}$$

$\lambda_p$— permissible bending stress coefficient of plating, generally taken 0.8, to be taken 0.9 as the calculated structural member is not contributing to the hull girder longitudinal strength;

$l$ — length of long edge of elementary plate panel taken along the side length, in m;

$s$ — length of short edge of elementary plate panel taken along the side length in way of middle of span $l$, in m;

$K_s$— coefficient, taken equal to:

$K_s$ =1.4 when steel coils are lined up in one tier with a key coil;

$K_s$ =1.0 in other cases;

$W_{SC}$— mass of one steel coil, in kg;

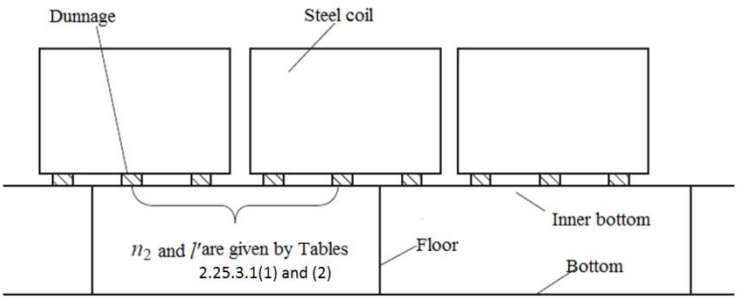
$R_{eH}$——minimum yield stress of material, in N/mm$^2$;

$n_1$— number of tiers of steel coils;

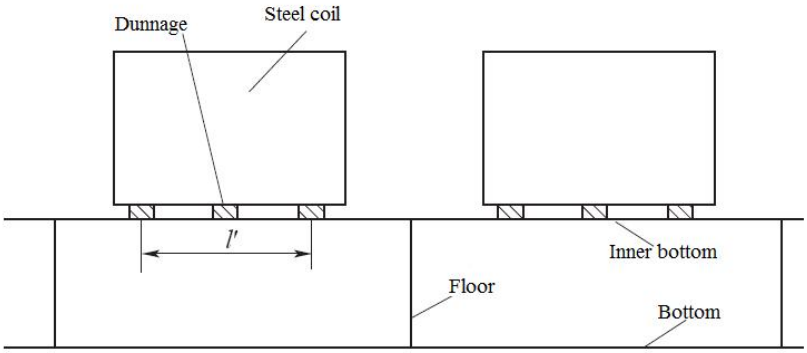
$n_2$— number of load points per elementary plate panel of inner bottom (see Figure 2.24.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.24.3.1(2)), $n_2 = n_3$ ; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.24.3.1(1)), $n_2$ is to be consistent with Table 2.24.3.1(1). For cases not included in Table 2.24.3.1(1), $n_2$ is to be determined in accordance with the following formula:

$$\frac{n_2 - 1}{n_3} + INT\left(\frac{n_2 - 1}{n_3}\right)\cdot 0.2 < \frac{l}{l_s} \le \frac{n_2}{n_3} + INT\left(\frac{n_2}{n_3}\right)\cdot 0.2$$

where: $INT(\ )$ is the integral function, taking the integral parts of values.




(1)




(2)

**Figure 2.24.3.1 Loading Condition of Steel Coils**

$n_3$ — number of dunnages supporting one steel coil;

$l_s$ — length of a steel coil, in m;

$K_2$ — coefficient taken equal to:

$$K_2 = -\frac{s}{l} + \sqrt{\left(\frac{s}{l}\right)^2 + 1.37\left(\frac{l}{s}\right)^2\left(1-\frac{l'}{l}\right)^2 + 2.33}$$

$l'$ — distance, in m, between outermost load points per elementary plate panel in ship's length (see Figure 2.24.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.24.3.1(2)), $l'$ is to be the distance between the dunnages of the external ends supporting the steel coils; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.24.3.1(1)), $l'$ is to be consistent with Table 2.24.3.1(2). For cases not included in Table 2.24.3.1(2), $l'$ is to be determined in accordance with the following formula:

$$l' = \left(\frac{n_2 - 1}{n_3} + 0.2 \cdot INT\left(\frac{n_2}{n_3}\right)\right) l_s$$

where: $INT(\ )$ is the integral function, taking the integral parts of values.

**Number $n_2$ of Load Points per Elementary Plate Panel Table 2.24.3.1(1)**

| $n_2$ | $n_3 = 2$ | $n_3 = 3$ | $n_3 = 4$ | $n_3 = 5$ |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | $0<\frac{l}{l_s}\le 0.5$ | $0<\frac{l}{l_s}\le 0.33$ | $0<\frac{l}{l_s}\le 0.25$ | $0<\frac{l}{l_s}\le 0.2$ |
| 2 | $0.5<\frac{l}{l_s}\le 1.2$ | $0.33<\frac{l}{l_s}\le 0.67$ | $0.25<\frac{l}{l_s}\le 0.5$ | $0.2<\frac{l}{l_s}\le 0.4$ |
| 3 | $1.2<\frac{l}{l_s}\le 1.7$ | $0.67<\frac{l}{l_s}\le 1.2$ | $0.5<\frac{l}{l_s}\le 0.75$ | $0.4<\frac{l}{l_s}\le 0.6$ |
| 4 | $1.7<\frac{l}{l_s}\le 2.4$ | $1.2<\frac{l}{l_s}\le 1.53$ | $0.75<\frac{l}{l_s}\le 1.2$ | $0.6<\frac{l}{l_s}\le 0.8$ |
| 5 | $2.4<\frac{l}{l_s}\le 2.9$ | $1.53<\frac{l}{l_s}\le 1.87$ | $1.2<\frac{l}{l_s}\le 1.45$ | $0.8<\frac{l}{l_s}\le 1.2$ |
| 6 | $2.9<\frac{l}{l_s}\le 3.6$ | $1.87<\frac{l}{l_s}\le 2.4$ | $1.45<\frac{l}{l_s}\le 1.7$ | $1.2<\frac{l}{l_s}\le 1.4$ |
| 7 | $3.6<\frac{l}{l_s}\le 4.1$ | $2.4<\frac{l}{l_s}\le 2.73$ | $1.7<\frac{l}{l_s}\le 1.95$ | $1.4<\frac{l}{l_s}\le 1.6$ |
| 8 | $4.1<\frac{l}{l_s}\le 4.8$ | $2.73<\frac{l}{l_s}\le 3.07$ | $1.95<\frac{l}{l_s}\le 2.4$ | $1.6<\frac{l}{l_s}\le 1.8$ |
| 9 | $4.8<\frac{l}{l_s}\le 5.3$ | $3.07<\frac{l}{l_s}\le 3.6$ | $2.4<\frac{l}{l_s}\le 2.65$ | $1.8<\frac{l}{l_s}\le 2.0$ |
| 10 | $5.3<\frac{l}{l_s}\le 6.0$ | $3.6<\frac{l}{l_s}\le 3.93$ | $2.65<\frac{l}{l_s}\le 2.9$ | $2.0<\frac{l}{l_s}\le 2.4$ |

**Distance between Load Points in Ship Length Direction per Elementary Plate Panel of Inner Bottom**

**Table 2.24.3.1(2)**

| $n_2$ | $n_3$ | | | |
|---|---|---|---|---|
| | 2 | 3 | 4 | 5 |
| 1 | Actual breadth of dunnage | | | |
| 2 | $0.5l_s$ | $0.33l_s$ | $0.25l_s$ | $0.2l_s$ |
| 3 | $1.2l_s$ | $0.67l_s$ | $0.50l_s$ | $0.4l_s$ |
| 4 | $1.7l_s$ | $1.20l_s$ | $0.75l_s$ | $0.6l_s$ |
| 5 | $2.4l_s$ | $1.53l_s$ | $1.20l_s$ | $0.8l_s$ |
| 6 | $2.9l_s$ | $1.87l_s$ | $1.45l_s$ | $1.2l_s$ |
| 7 | $3.6l_s$ | $2.40l_s$ | $1.70l_s$ | $1.4l_s$ |
| 8 | $4.1l_s$ | $2.73l_s$ | $1.95l_s$ | $1.6l_s$ |
| 9 | $4.8l_s$ | $3.07l_s$ | $2.40l_s$ | $1.8l_s$ |
| 10 | $5.3l_s$ | $3.60l_s$ | $2.65l_s$ | $2.0l_s$ |

### 2.24.4 Bilge hopper sloping plate and inner hull plate

2.24.4.1 The thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{a_{hopper}F_{SC}^{'}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: $K_1$— coefficient, defined in 2.24.3;

$t_c$ ——corrosion addition, in mm, generally taken 2.5 mm, to be taken 3.5 mm for bilge hopper sloping plate and inner hull plate within 1.5 m height from the lowest point of inner bottom where the cargo holds are designed for loading/unloading by grabs;

$R_{eH}$——minimum yield stress of material, N/mm$^2$;

$\theta_h$ — angle, in degree, between inner bottom plate and bilge hopper sloping plate or inner hull plate, see Figure 2.24.1.2;

$\theta_h$ — see the formula stipulated in 1.5.2 of Section 5, Chapter 1 in this Part,in degree;

$a_{hopper}$— factor taken equal to:

$$a_{hopper} = -a_R \sin\left(\tan^{-1}\left|\frac{y_{G-SC}}{R}\right| - \theta_h\right) + g\cos\left(\theta_h - \varphi_m\right)$$

$a_R$— tangential acceleration defined in 2.24.2;

$g$ — acceleration due to gravity, $g$ = 9.81 m/s$^2$;

$y_{G\text{-}SC}$— centre of gravity in transverse direction, in m, defined in 2.24.2;

$R$— factor, defined in 2.24.2;

$F'_{SC}$—equivalent mass of steel coils, in kg, taken equal to:

$$F'_{SC} = C_k \cdot \frac{W_{SC} n_2}{n_3}$$

$\lambda_p$—permissible bending stress coefficient of plating, defined in 2.24.3;

$C_k$ — coefficient, taken equal to:

$C_k$ =3.2, when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate;

$C_k$ =2.0, in other cases.

### 2.24.5 Stiffeners of inner bottom

2.24.5.1 The section modulus $W$ and the shear area $A$ of single span stiffeners located on inner bottom plating are not to be less than the values obtained from the following formulae:

$$W = 1.1K_3 \frac{\left(g + 0.5a_v\right)F_{SC}}{8\lambda_s R_{eH}} \qquad \text{cm}^3$$

$$A = \frac{5\left(g + 0.5a_v\right)F_{SC}}{0.9\tau_{eH}\sin\phi} \times 10^{-3} \qquad \text{cm}^2$$

where: $K_3$— coefficient, defined in Table 2.24.5.1, to be taken as $2l_e/3$ for $n_2 > 10$;

$l_e$ — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;

$a_v$— vertical acceleration, in m/s$^2$, calculated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART;

$g$ — acceleration due to gravity, $g$ = 9.81 m/s$^2$;

$F_{SC}$—equivalent mass of steel coils, in kg, defined in 2.24.3;

$R_{eH}$ — minimum yield stress of material, in N/mm$^2$;

$\tau_a$ — shear strength, in N/mm$^2$, taken equal to:

$\lambda_s$ ——permissible bending stress coefficient of stiffeners, taken 0.9;

$\tau_{eH}$ ——shear yield stress of material, in N/mm$^2$, taken equal to:

$$\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$$

$\phi$ — angle between stiffener web and shell plating, in degree, to be taken at the middle of span of stiffener.

**Coefficient $K_3$ Table 2.24.5.1**

| $n_2$ | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| $K_3$ | $l_e$ | $l_e - \frac{l'^2}{l_e}$ | $l_e - \frac{2l'^2}{3l_e}$ | $l_e - \frac{5l'^2}{9l_e}$ | $l_e - \frac{7l'^2}{15l_e}$ | $l_e - \frac{4l'^2}{9l_e}$ | $l_e - \frac{3l'^2}{7l_e}$ | $l_e - \frac{5l'^2}{12l_e}$ | $l_e - \frac{11l'^2}{27l_e}$ |

### 2.24.6 Stiffeners located on bilge hopper sloping plate or inner hull plate

2.24.6.1 The section modulus $W$ and the net shear area $A$ of single span stiffeners located on bilge hopper sloping plate and inner hull plate are not to be less than the values obtained from the following formulae:

$$W = 1.1K_3 \frac{a_{hopper} F'_{SC}}{8\lambda_s R_{eH}} \quad \text{cm}^3$$

$$A = \frac{5a_{hopper} F'_{SC}}{0.9\tau_{eH} \sin\phi} \times 10^{-3} \quad \text{cm}^2$$

where: $K_3$— coefficient, defined in Table 2.24.5.1, to be taken as $2l_e/3$ for $n_2 > 10$;

$l_e$ — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;

$R_{eH}$ — minimum yield stress of material, in N/mm$^2$;

$a_{hopper}$ — coefficient, defined in 2.24.4.1;

$\tau_{eH}$ — shear yield stress of material, in N/mm$^2$, see 2.24.5.1;

$\lambda_s$ ——permissible bending stress coefficient of stiffeners, see 2.24.5.1;

$F'_{SC}$—equivalent mass of steel coils, in kg, defined in 2.24.4;

$\phi$ — angle, in degree, defined in 2.24.5.

# Appendix 1 LOADING INSTRUMENTS

## 1 General Requirements

### 1.1 Application

1.1.1 This Appendix applies to loading instruments consisting of the onboard computer system as required by 2.2.8 of this Chapter.

### 1.2 Inspections of loading instruments

1.2.1 Inspections of loading instruments include hardware inspection, software approval, actual installation inspection and inspection after construction. Steps of implementation for inspections of loading instruments are shown in Figure 1.2.1.

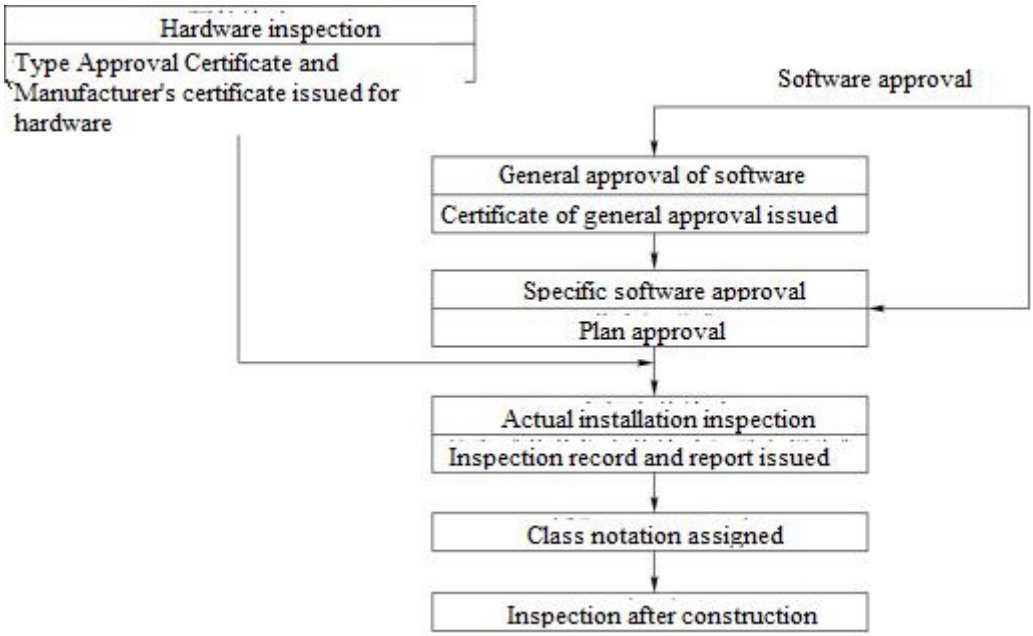



**Figure 1.2.1 Steps of Implementation for Surveys of Loading Instruments**

1.2.2 Software approval may be carried out by either one of the following two methods:

(1) On completion of general approval of software, software approval is carried out for a specific ship;

(2) Software approval is carried out directly to a specific ship.

1.2.3 Provision of loading instruments on board the ship may be made by either one of the following two methods:

(1) a single loading instrument to be provided on board the ship;

(2) two same loading instruments to be provided on board the ship, one for main use and the other as standby.

## 2 Hardware Inspections

## 2.1 General requirements

2.1.1 Loading instrument hardware inspections are to be carried out in accordance with the requirements for inspections of products in Chapter 3 of PART ONE of the CCS Rules for Classification of Sea-going Steel Ships and this Section and, in general, consist of examination of plans and documents, type tests.

2.1.2 Hardware of loading instruments consists, in general, of computers and peripheral apparatus, where the printer is supplied as a separate unit from the computer, the type test of such a printer is not necessary.

2.1.3 Where two available loading instruments are installed onboard a ship, type approval certificate may be exempted, however, installation test is to be carried out.

## 2.2 Plans and documents

2.2.1 Where an application for hardware inspections is made, the following plans and documents should be submitted for approval:

(1) Technical specifications of hardware and peripheral apparatus;

(2) Fixing and installation of loading instruments;

(3) Type test program.

## 2.3 Type tests

2.3.1 Type tests are to be carried out in a verification and test organization and, in general, with the presence of the surveyor.

2.3.2 Type test items

(1) Visual inspection;

(2) Performance;

(3) Electric power supply variations;

(4) Dry heat;

(5) Damp heat;

(6) Vibration;

(7) Inclination and rolling;

(8) Protection by enclosure;

(9) Low temperatures;

(10) Electromagnetic compatibility.

2.3.3 Where the loading instruments, of which hardware is installed in an air-conditioned room, are used only for the purpose of calculation, and no input of external signals or output of control signals is made, the items of type tests may be suitably reduced.

2.3.4 Where one main computer together with a standby one are provided onboard the ship, the hardware may not be subject to the type tests.

2.3.5 For the methods used in type tests, reference may be made to CCS Guidelines for Type Approval Test of Electric and Electronic Products or the relevant requirements of acceptable standards.

## 3 Functional Requirements for Software

### 3.1 General requirements

3.1.1 The functions of loading instruments are to cover at least calculating and indicating still water bending moment and shear force at the specified hull positions in any loading condition or light ship condition quickly and easily. Where applicable, the maximum permissible value of a still water torsional moment resulted from the non-uniform loading of cargoes is to be indicated.

3.1.2 Single point loading instruments (i.e. with only one check point on board the ship) are not acceptable to CCS.

3.1.3 Loading instruments are not to be substituted for the approved or confirmed final loading manual or stability information (hereinafter referred to as the final loading manual), and the results of the calculations are only applicable to the ship for which it has been approved.

3.1.4 For a specific ship, the requirements for overall strength are mandatory.Where the installed loading instruments have the function of stability calculations, however, the stability calculation software is to be capable of calculations for all stability requirements (including intact stability, grain-carrying stability and damage stability), either as mandatory or non-mandatory ones, applicable to the ship and is to contain relevant stability information, subject to the approval.

3.1.5 It is recommended that software be provided with an online help function, i.e. the software system may provide online help for input, output, calculation and printing.

3.1.6 The software is to be such that a common user can not alter the inputted data of the actual ship such as the geometrical characteristics, light ship weight, centre of gravity, capacity table, curve of allowable values.

3.1.7 The software is to be such that any user can not alter the inputted application programs.

3.1.8 The software is to, as far as possible, reduce significant or illogical input errors and alert the user to any input value exceeding the actual maximum capacity of a compartment or any negative value of the capacity.

3.1.9 The software is to be capable of clearly judging whether a loading condition complies with the relevant requirements, i.e. calculating for a certain loading condition. Where the calculation results exceed the permissible values, the user is to be alerted by distinct means such as prominent display, special markings or visible and audible alarms, screen display or printout.

3.1.10 The software is to be provided with passwords so that the computer will refuse to work and alert the user where any illegal password is input.

3.1.11 The software is to be at least capable of calculating the displacement and centre of gravity in any loading conditions and completing calculation and criteria of overall strength (and stability, if applicable) of the ship, displaying and printing out date and time of performing calculation and saving calculation results. All input data and calculation results displayed on the screen and printed out, including the fore and after draughts, are to be in definite and uniform measurement units and easily comparable with the approved final loading manual to avoid possible confusion and misunderstanding, with the identification marking and version number of the software being clearly indicated on each printed page.

3.1.12 The software interface is to be fully user-friendly and to alert the user to any operational error. Data loss or dead stop of the computer caused by the user’s error is to be minimized.

### 3.2 Overall strength

3.2.1 The functional requirements for software in respect to overall strength are given in 2.2.8 of this Chapter.

### 3.3 Intact stability

3.3.1 The software is to use direct calculation to check intact stability and the following requirements are to be met:

(1) The software is to be capable of calculating and displaying the height of the centre of gravity and initial metacentric height of the ship and correcting free surface effects and comparing such values with the permissible values, where applicable. If any permissible value is exceeded, an alarm is to be automatically initiated.

(2) The software is to be at least capable of calculating and displaying *GZ* curves and correcting free surface effects.

(3) The software is to be capable of calculating the intact stability in any loading conditions and achieving the criteria for intact stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual and any other method used for this purpose is to be indicated in submissions and subject to agreement of CCS plan approval unit. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.3.2 If damage stability is checked by the software according to the provisions of 3.5.2 of this Section, intact stability can be checked based on the same method.

### 3.4 Stability for carriage of grain in bulk

3.4.1 The software is to be in compliance with the relevant requirements in 3.3.

3.4.2 The software is to be capable of inputting the permissible inclining moment curves.

3.4.3 The software is to be capable of calculating the stability for the carriage of grain in bulk and achieving the criteria for the stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is at least to be able to calculate the inclining moment of actual shift of grain and the permissible inclining moment to which comparison is made. The software is to be capable of automatically initiating an alarm in case of any permissible value being exceeded.

### 3.5 Damage stability

3.5.1 If the software uses direct calculation to check damage stability, the following requirements are to be met:

(1) The software is to indicate whether the calculation is performed by means of loss of buoyancy or increase of weight, and the former is recommended.

(2) The software is to be capable of making corrections of free surface effects for *GZ* curves.

(3) The software is to be capable of allowing for corrections for liquid loss of damaged tanks.

(4) The software is to define the damaged compartment(s) and associated damage conditions in advance for selection by the crew in calculation, and be capable of calculating and displaying the *GZ* curves after damage.

(5) The software is to be capable of calculating the equilibrium position and stability in any damage condition, covering fore, after and mean draughts, trimming values, heeling angles, distance from equilibrium waterline to flooding openings, residual initial metacentric height,

residual stability etc., and achieving the criteria for damage stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.5.2 If damage stability is checked by the software on the basis of approved limit curves (the curve of permissible vertical position of the centre of gravity or the curve of permissible initial metacentric heights) or loading conditions, the following requirements are to be met:

(1) The software is to be capable of calculating and displaying displacement, the position of the centre of gravity, buoyancy and initial metacentric height of the ship in any loading condition and correcting free surface effects as required and comparing such values with the approved data.

(2) The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded (if limit curves are used) or any acceptable and safe tolerance being exceeded (compared with loading condition).

### 3.6 Additional requirements for bulk carriers, ore carriers and combination carriers

3.6.1 In addition to the above requirements, the loading instruments on board bulk carriers, ore carriers and combination carriers are to comply with the requirements of Section 7, Chapter 8 of this PART.

## 4 Software Approval

### 4.1 General requirements

4.1.1 Software approval consists of general approval and specific approval, covering:

(1) verification that the data used are consistent with the current condition of the ship;

(2) verification and approval of the test conditions;

(3) verification that the software is appropriate for the required type of ship and corresponding calculations.

### 4.2 Requirements for general approval of software

4.2.1 The general approval of software of loading instruments means approval of design and calculation programs of the software, i.e. approval of the design methods, calculation functions and principles and relevant documents for programing and usage of the said software through actual tests on representative ships selected according to the submitted scope of application.

4.2.2 The general approval of software of loading instruments may specifically include the following:

(1) Design methods, calculation functions and principles of the software are to be in conformity with the classification/statutory requirements and comply with the relevant requirements in section 3 of this Appendix.

(2) For ships of different types selected for tests, the calculation results for the typical loading conditions selected according 4.6 of this Appendix are, by comparison with those of the approved loading manual or plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.

(3) User's operation manual of loading instruments is to comply with the relevant requirements in 4.8 of this Appendix.

4.2.3 A Certificate of General Approval of Software of Loading Instruments is to be issued subject to general approval.

4.2.4 The application and restrictions, e.g. applicable ship types and functional restrictions, are to be noted on the Certificate of General Approval of Software of Loading Instruments.

4.2.5 A Certificate of General Approval of Software of Loading Instruments remains valid for a period not exceeding 5 years. When the certificate expires and if the applicant confirms that no change has been made to the version of the said software, the Certificate of General Approval of Software of Loading Instruments will be renewed. However, the plan approval unit responsible for the software approval is to carry out nonscheduled assessments of the software as necessary, e.g. in response to complaints from users.

4.2.6 Where the applicant has made any change to the software without re-approval, the issued Certificate of General Approval of Software of Loading Instruments is no longer valid.

4.2.7 Where the version of the loading instrument software, of which general approval is granted, is upgraded or changed, resubmission for approval is required. Submission of plans and documents which are the same as those for the approved version is unnecessary, but the applicant should indicate this in the application.

### 4.3 Steps of implementation for general approval of software

4.3.1 The general approval of software of loading instruments is to be carried out in accordance with the relevant requirements for plan approval.

4.3.2 The applicant is to fill in an application for software approval of loading instruments. For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.3.3 The test ships are to be so selected that all ship types and their functions as required in the application are covered. And the following are to be complied with:

(1) for the strength calculation software, the applicant is to select the calculation results for at least one test ship, which may be either the sample ship provided by CCS or the one determined by the applicant. Where the latter is selected, the prior agreement of the plan approval unit is necessary;

(2) for the stability calculation software, test ships are to be selected in accordance with 6.1 of Appendix 2 of this Chapter.

4.3.4 The applicant is to submit the following plans and documents to plan approval unit. After examination and approval, one set of their copies is to be returned to the applicant, one set sent to the Headquarters and one set filed by the plan approval unit (where application for specific approval of the software is made for the test ship at the same time, an additional copy of the user's operation manual and that of the calculation and test report are required for survey unit):

(1) Specification of the software system (for information), covering design method, calculation functions and principles, data structure as well as flowchart of the software, and explaining functional items as determined in the application and computational accuracy of the software such as methods used for numerical integration, interpolation, etc.

(2) User's operation manual of loading instruments (for information).

(3) Data of test ship(s) inputted in the software (for information), such as main dimensions, lightweight distribution and centre of gravity, Bonjean curves, hydrostatic data, tank capacity,

permissible still water shear forces, permissible still water bending moments and, where applicable, correction factors of bulkhead shear forces and permissible still water torsional moments. Where the software has computation functions for intact stability, stability for the carriage of grain in bulk, damage stability, etc., corresponding data are also to be submitted for approval.

(4) Test report of loading calculations (for approval) for conditions to be selected according to the requirements in 4.6 of this Appendix with the agreement of the plan approval unit, covering the input data and all output results.

(5) General arrangement, lines, final loading manual of the test ship(s) and other additional plans or data required for information or use in check calculations.

(6) A set of installation discs, including the executing software and internal testing data.

4.3.5 On satisfactory completion of examination of the above-mentioned plans and documents, the Certificate of Software Approval of Loading Instruments may be issued.

### 4.4 Requirements for specific approval of software

4.4.1 The specific approval of software means, for the purpose of a specific ship, the approval of loading instrument's software installed on board, i.e. the approval of the design method, calculation functions and principles, input data, user's operation manual, full-scale test report and other documents.

4.4.2 The specific approval of software may specifically include the following:

(1) Design methods, calculation functions and principles of the software are to be in conformity with the classification requirements and comply with the relevant requirements in section 3 of this Appendix.

(2) All input data of the software are to be consistent with those of the actual ship, i.e. being taken from the finished documents approved or confirmed, and in particular the lightweight and centre of gravity are to be taken from the inclining test report. Where the software is capable of stability calculation, the input data are to comply with paragraph 6.2 of Appendix 2.

(3) The computation points along the ship's length and their number are to comply with the rules.

(4) The permissible still water bending moments, permissible still water shear forces, and where applicable, permissible still water torsional moments and correction factors of bulkhead shear forces at the computation points along the ship's length are to be correctly calculated and in consistent with those in the final loading manual.

(5) The calculation results for the typical loading conditions selected according to 4.6 of this Appendix are, by comparison with those of the final loading manual or plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.

(6) User's operation manual of the loading instrument is to comply with the requirements in 4.8 of this Appendix.

4.4.3 For software with a Certificate of General Approval of Software of Loading Instruments and in respect to the applicable ship types and functions stated in the Certificate, where application is made for specific approval of the software, submission of design methods, calculation functions and principles of the software is unnecessary.

4.4.4 For software without a Certificate of General Approval of Software of Loading Instruments, the applicant may directly apply for specific approval of loading instrument software.

### 4.5 Steps of implementation for specific approval of software

4.5.1 The specific approval of software is to be carried out in accordance with the relevantplan approval requirements.

4.5.2 For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.5.3 The applicant is to submit the following plans and documents:

(1) For software without general approval, the applicable contents for the specific ship as required in (1), (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix are to be submitted.

(2) For software with general approval, the applicable contents for the specific ship as required in (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix and a copy of the Certificate of General Approval of Software of Loading Instruments are to be submitted.

### 4.6 Test conditions

4.6.1 Test conditions are to be selected from the final loading manual.

4.6.2 Test conditions are at least to contain loading conditions for the following:

(1) for minimum displacement, such as lightship condition or arrival condition with light ballast;

(2) for maximum still water bending moment, such as ballast or partially loaded conditions;

(3) for maximum displacement, such as fully loaded conditions;

(4) any condition resulting in extremely large still water shear force, such as ore loaded in alternate holds, etc.;

(5) where the software is capable of the stability calculation for carriage of grain in bulk, the test conditions are to include the one of a fully loaded hold with even filling at its ends, the one of a fully loaded hold with uneven filing at its ends and the one of a partly loaded hold;

(6) where the software is capable of both intact stability calculation and damage stability calculation, the necessary typical conditions are to comply with paragraph 6.2 of Appendix 2.

4.6.3 The test conditions are to contain the arrival and departure conditions and cover all loaded holds and all functions of the software as far as possible.

4.6.4 The approved test conditions are to be stored as input data in such a way that no user can alter them. A copy of the approved test conditions is to be available on board.

### 4.7 Permissible values and error control

4.7.1 All selected permissible values and the calculation points along the ship's length are to be taken from the approved finished documents.

4.7.2 The curves of still water shear forces and still water bending moments are to be consistent with the corresponding curve tendency in the final loading manual. The peak value of still water bending moment is normally to occur at the position where the still water shear force is zero.

4.7.3 The maximum values of still water shear force, still water bending moment and still water torsional moment and their calculated values at the calculation points along the ship's length are, as compared with the calculation results of the final loading manual, to have their errors controlled within the ranges given in Table 4.7.3.

**Error Control** **Table 4.7.3**

| | Error (in comparison to approved value, %) |
|---|---|
| Still water shear force | ≤ ± 5% |
| Still water bending moment | ≤ ± 5% |
| Still water torsional moment | ≤ ± 5% |

4.7.4 The errors of the software in stability calculation are to comply with paragraph 5 of Appendix 2.

4.7.5 During examination, where the errors of the calculated values for individual calculation points of the loading instrument are significant as compared with the values of the final loading manual and no adequate evidence is available for wrong calculation of the loading instrument, check is to be made by using CCS plan approval software and the calculation results by this software are to be accepted as standard ones. Where any principled error is found in the final loading manual, the unit which has approved the manual is to be informed of this matter together with the recommendation that the existing loading manual be revised.

### 4.8 Operation manual

4.8.1 At least one copy of the operation manual of loading instrument of the ship is to be kept on board.

4.8.2 The operation manual of loading instrument is to be written in a language used by the users on board, and the language is to be the same as that used for screen display, printout and the approved final loading manual kept on board. Where the language is not English, an English translation is to be available.

4.8.3 The operation manual is to be written in a clear and unambiguous manner. The use of flowcharts is recommended for illustrating operational processes.

4.8.4 The operation manual is to contain the following:

(1) particulars and version number of the software;

(2) a copy of the Certificate of General Approval of Software of Loading Instruments (where applicable);

(3) specification of hardware needed to run the software and guidance for software installation;

(4) software running steps shown in menus and dialogues, description of error messages and warnings likely to be encountered and unambiguous instructions for subsequent actions to be taken by the user in each case;

(5) lightweight and coordinates of centre of gravity;

(6) full deadweight description of each test condition for loading calculation;

(7) diagrams of the permissible still water shear forces and still water bending moments and where applicable, the permissible cargo torque;

(8) where applicable, shear force correction factors;

(9) operation procedure shown by calculation cases;

(10) input and output data, calculation results shown by screen display, with necessary explanatory text;

(11) explanation for function keys.

## 5 Actual Installation Inspections

### 5.1 General requirements

5.1.1 The Owner or the entrusting party is to submit application to survey unit situated at the port of call of the ship.

5.1.2 The crew may master the operation and calculation of the loading instrument on board through learning or training. The installation inspection is to be carried out by the crew.

5.1.3 Actual installation inspection is to be carried out soon after the loading instrument has been installed on board the ship for verification of satisfactory operation and calculation and for check of strength and stability. Where by that time the final loading manual has not been approved, the installation inspection may be postponed until the manual is approved.

**5.2 Inspections and tests**

5.2.1 Where the loading instruments are provided as a main computer and a standby one on board a ship, installation inspections are to be carried out respectively and both computers are to be found satisfactory.

5.2.2 The installation inspections are to be carried out in the presence of surveyor. The following items are to be included in the installation inspections:

(1) checking the certificate of hardware;

(2) checking that the user's operation manual and test report of loading calculation are kept on board the ship;

(3) examining the environment and position for installing the system: confirming that the position and method for installing the system are as required in the specification;

(4) system stability testing: the computer system is to be capable of working normally after a continuous running period of one hour;

(5) self-checking capability tests of hardware and peripheral apparatus: self-check tests to be carried out according to the specification for hardware and peripheral apparatus with self-check capability;

(6) transient power failure test: re-starting the system after a period of 30 s of transient power failure, and confirming that:

① it is still capable of working normally; and

② its programs and data are not lost;

(7) software security tests: where an illegal password is inputted (or in case of human maloperation), the system should refuse to work;

(8) software safety tests: a common user is not to be capable of changing the application program and the input ship's data such as geometrical characteristics, tank capacity table, curve of permissible values;

(9) system performance tests: the calculation results from the system operated by the crew of the ship based upon the loading conditions as stated in the approved test report of loading calculations are to be the same as those in the approved test report. Where the software is capable of stability calculation, tests are also to comply with paragraph 8 of Appendix 2.

5.2.3 The test report of loading calculations printed out by the loading instrument during installation inspection is to be confirmed and signed by the attending Surveyor. After satisfactory installation inspection, the attending Surveyor will issue a report.

**5.3 Inspections of existing loading instruments on board ships**

5.3.1 For ships provided with loading instruments approved by other member Societies of IACS, the operation manual, test report of loading calculations approved and related certificates of loading instrument hardware and software issued by these Societies may be reviewed, and installation inspections are to be carried out in accordance with 5.2.2 of this Appendix.

5.3.2 For ships provided with loading instruments not complying with the relevant requirements

of CCS or approved by a party which is not member of IACS, installation inspections are to be carried out once again.

# Appendix 2 COMPUTER SOFTWARE FOR ONBOARD STABILITY CALCULATIONS

**Application**

Stability software installed onboard is to cover all mandatory statutory intact and damage stability requirements applicable to the ship. This Appendix, requires approval of software installed on onboard computers which is capable of performing stability calculations.

Active and passive systems are defined in paragraph 2. This Appendix covers passive systems and the off-line operation mode of active systems only.

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## 1 General

- The scope of a stability calculation software is to be in accordance with the approved stability information and is at least to include all information and perform all calculations or checks as necessary to ensure compliance with the applicable stability requirements.
- Approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.
- The input/output information is to be easily comparable with approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.
- An operation manual is to be provided for the onboard computer stability software.
- The language in which the stability information is displayed and printed out as well as the operation manual written is to be the same as used in the ship's approved stability information. The stability information may be required to translate into Chinese.
- The onboard computer software for stability calculations is to be ship specific and the results of the calculations are to be only applicable to the ship for which it has been approved.
- In case of modifications implying changes in the main data or internal arrangement of the ship, the specific approval of any original stability calculation software is no longer valid. The software is to be modified accordingly and reapproved.

## 2 Calculation Systems

A passive system requires manual data entry;

an active system replaces the manual entry with sensors reading and entering the contents of tanks, etc.; and

a third system, an integrated system, controls or initiates actions based on the sensor-supplied inputs and is not within the scope of this Appendix.

## 3 Types of Stability Software

Four types of calculations performed by stability software are acceptable depending upon a vessel's stability requirements:

Type 1

Software calculating intact stability only (for vessels not required to meet a damage stability criterion).

Type 2

Software calculating intact stability and checking damage stability on basis of a limit curve or checking all the stability requirements (intact and damage stability) on the basis of a limit curve.

Type 3

Software calculating intact stability and damage stability by direct application of preprogrammed damage cases based on the relevant Conventions or Codes for each loading condition (for some tankers, etc.).

Type 4

Software calculating damage stability associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port (SRtP).

Damage stability of both Type 3 and Type 4 stability software is to be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model.

## 4 Functional Requirements

### 4.1 General requirements for any type of stability software

4.1.1 The calculation program is to present relevant parameters of each loading condition in order to assist the Master in his judgement on whether the ship is loaded within the approval limits. The following parameters are to be presented for a given loading condition:

− deadweight data;
− lightship data;
− trim;
− draft at the draft marks and perpendiculars;
− summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
− downflooding angle and corresponding downflooding opening (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, downflooding angle and the corresponding downflooding opening are to be indicated);
− compliance with stability criteria: Listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled) (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, the limit values, the obtained values and the conclusion are to be indicated).

4.1.2 A clear warning is to be given on screen and in hard copy printout if any of the loading limitations are not complied with.

Loading limitations are to include, but may not be limited to:

− Trim, draught, liquid densities, tank filling levels, initial heel;
− Use of limit KG/GM curves in conjunction with above for Type 2;
− Restrictions to the stowage height for timber where timber load lines are assigned.

4.1.3 Type 3 software is to include pre-defined relevant damage cases for both sides of the ship according to the applicable rules for automatic check of a given loading condition.

4.1.4 The date and time of a saved calculation are to be part of the screen display and hard copy

printout.

4.1.5 Each hard copy printout is to contain identification of the calculation program including version number.

4.1.6 Units of measurement are to be clearly identified and used consistently within a loading calculation.

4.1.7 For Type 3 and Type 4 software, the system is to be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

4.1.8 For Type 1 and Type 2 software, in case a full three dimensional model is used for stability calculations, the requirements of the computer model are to be as per paragraph 4.1.7 above to the extent as applicable and according to the type of stability software.

### 4.2 Further requirements for Type 4 stability software

4.2.1 The normal (Type 1, 2 and 3) and SRtP (Type 4) software need not be "totally separated". Where the normal and SRtP software are not totally separated:

− the function of switching between normal software and Type 4 software is to be provided.

− the actual intact loading condition is to be the same for both functions (normal operation and SRtP); and

− the SRtP module needs only to be activated in case of an incident.

Approval of Type 4 (SRtP) software is for stability only.

4.2.2 In passenger ships which are subject to SRtP and have an onboard stability computer and shore-based support, such software need not be identical.

4.2.3 Each internal space is to be assigned its permeability as shown below, unless a more accurate permeability has been reflected in the approved stability information.

| Space | Permeability | | | |
|---|---|---|---|---|
| | Default | Full | Partially filled | Empty |
| Container Spaces | 0.95 | 0.70 | 0.80 | 0.95 |
| Dry Cargo spaces | 0.95 | 0.70 | 0.80 | 0.95 |
| Ro-Ro spaces | 0.95 | 0.90 | 0.90 | 0.95 |
| Cargo liquids | 0.95 | 0.70 | 0.80 | 0.95 |
| Intended for consumable liquids | 0.95 | 0.95 | 0.95 | 0.95 |
| Stores | 0.95 | 0.60 | (0.60) | 0.95 |
| Occupied by machinery | 0.85 | | | |
| Void spaces | 0.95 | | | |
| Occupied by accommodation | 0.95 | | | |

4.2.4 The system is to be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

4.2.5 The system is to account for the effect of wind by using the method in Technical Regulations for Statutory Survey of Sea-going Ships Engaged on Domestic Voyages as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different ($P = 120\ N/m^2$ equates to Beaufort 6; approximately 13.8 m/s or 27 knots).

4.2.6 The system is to be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation is to be done and presented, taking into account any watertight door located within the damaged compartment(s)).

4.2.7 The system is to utilize the latest approved lightship weight and centre of gravity information.

4.2.8 The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship.

When the actual loading condition is input in the SRtP software, the following output (intact stability) is to be available:

− deadweight data;
− lightship data;
− trim;
− heel;
− draft at the draft marks and perpendiculars;
− summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
− downflooding angle and corresponding downflooding opening;
− free surfaces;
− GM value;
− GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0°, 5°, 10°, 15°, 20°, 25°, 30°, 40°, 50° and 60° ;
− compliance with relevant intact stability criteria : listing of all calculated intact stability criteria, the limiting values, the obtained values and the evaluation (criteria fulfilled or not fulfilled);
− GM/KG limiting curve required in Technical Regulations for Statutory Survey of Sea-going Ships Engaged on Domestic Voyages;When the actual loading condition is associated to the actual damage case(s) due to the casualty, the following output (damage stability) is to be available:
− trim;
− heel;
− draft at the draft marks and perpendiculars;
− progressive flooding angle and corresponding progressive flooding openings;
− GM value;
− GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg;
− compliance with stability criteria: listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled);
− the survivability criteria for Type 4 software (SRtP) are left to the discretion of the Administration;
− relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point;
− list of all flooded compartments with the permeability considered;
− amount of water in each flooded compartment;
− escape route immersion angles;

− a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

## 5 Acceptable Tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to 5.1 or 5.2. Deviation from these tolerances is not to be accepted unless it considers that there is a satisfactory explanation for the difference and that there will be no adverse effect on the safety of the ship.

Examples of pre-programmed input data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, $KM_t$ and MCT versus draught.

Stability data: KN or MS values at appropriate heel/trim angles versus displacement, stability limits.

Compartment data: Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

Examples of output data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, $KM_t$ and MCT versus draught as well as actual draughts, trim.

Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria, e.g. areas under the GZ curve, weather criteria.

Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

The computational accuracy of the calculation program results is to be within the acceptable tolerances, specified in 5.1 or 5.2, of the results using an independent program or the approved stability information with identical input.

5.1 Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations, are to have zero tolerances for the printouts of input data. Output data tolerances are to be close to zero, however, small differences associated with calculation rounding or abridged input data are acceptable. Additionally differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information are acceptable after review.

5.2 Programs which use hull form models as their basis for stability calculations, are to have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approved model. Acceptable tolerances are to be in accordance with Table 1.

**Table 1**

| | |
|---|---|
| **Hull Form Dependent** | |
| Displacement | +/- 2% |
| Longitudinal center of buoyancy, from *AP* | +/- 1%/50 cm |
| Vertical center of bouyancy | +/- 1%/5 cm |
| Transverse center of bouyancy | +/- 0.5% of *B*/ 5 cm |
| Longitudinal center of flotation, from *AP* | +/- 1%/50 cm |
| Moment to trim 1 cm | +/- 2% |
| Transverse metacentric height | +/- 1%/5 cm |
| Longitudinal metacentric height | +/- 1%/50 cm |
| Cross curves of stability | +/- 5 cm |
| **Compartment dependent** | |
| Volume or deadweight | +/- 2% |
| Longitudinal center of gravity, from *AP* | +/- 1%/50 cm |
| Vertical centre of gravity | +/- 1%/5 cm |
| Transverse center of gravity | +/- 0.5% of *B*/5 cm |
| Free surface moment | +/- 2% |
| Shifting moment | +/- 5% |
| Level of contents | +/- 2% |
| **Trim and stability** | |
| Draughts (forward, aft, mean) | +/- 1%/5 cm |
| $GM_t$ (both solid and corrected for free surfaces) | +/- 1%/5 cm |
| *GZ* values | +/- 5% /5 cm |
| Downflooding angle | +/- 2° |
| Equilibrium angles | +/- 1° |
| Distance from *WL* to unprotected and weathertight openings, or other relevant point, if applicable | +/- 5%/5 cm |
| Areas under righting arm curve | +/- 5% / 0.0012 m · rad |

Notes:

1. Deviation in % = [(base value − applicant's value)/base value] × 100

where the "base value" may be from the approved stability information or the approved computer model.

2. When applying the tolerances in Table 1 having two values, the allowable tolerance is the greater of the two values.

3. Where differences in calculation methodology exist between the programs used in the comparison, this may be a basis for accepting deviations greater than that specified in Table 1 provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.

4. Deviation from these tolerances are not to be accepted unless it considers that there is a satisfactory explanation for the difference and that it is clearly evident from the stability calculations that the deviation does not impact compliance with the required stability criteria for the ship under consideration.

## 6 Approval Procedure

### Conditions of approval of the onboard software for stability calculations

The onboard software used for stability calculations is subject to approval, which is to include:

- verification of type approval, if any;
- verification that the data used are consistent with the current condition of the ship (refer to paragraph 6.2);
- verification and approval of the test conditions;
- verification that the software is appropriate for the type of ship and stability calculations required;
- verification of functional requirements under paragraph 4.1.2.

The satisfactory operation of the software with the onboard computer(s) for stability calculations is to be verified by testing upon installation (refer to paragraph 8). A copy of the approved test conditions and the operation manual for the computer/software are to be available on board.

**6.1 General Approval (optional)**

Upon application for general approval of the calculation program, it may provide the applicant with test data consisting of two or more design data sets, each of which is to include a ship's hull form data, compartmentation data, lightship characteristics and deadweight data, in sufficient detail to accurately define the ship and its loading condition. Acceptable hull form and compartmentation data may be in the form of surface coordinates for modeling the hull form and compartment boundaries, e.g: a table of offsets, or in the form of pre-calculated tabular data, e.g: hydrostatic tables, capacity tables, etc., depending upon the form of data used by the software being submitted for approval. Alternatively, the general approval may be given based on at least two test ships.

In general, the software is to be tested for two types of ships for which approval is requested, with at least one design data set for each of the two types. Where approval is requested for only one type of ship, a minimum of two data sets for different hull forms of that type of ship are required to be tested. For calculation software which is based on the input of hull form data, design data sets is to be provided for three types of ships for which the software is to be approved, or a minimum of three data sets for different hull forms if approval is requested for only one type of ship. Representative ship types which require different design data sets due to their hull forms, typical arrangements, and nature of cargo include: tanker, bulk carrier, container ship, and other dry cargo and passenger ships. The test data sets are to be used by the applicant to run the calculation program for the test ships. The results obtained (together with the hydrostatic data and cross-curve data developed by the program, if appropriate) are to be submitted for the assessment of the program's computational accuracy. Parallel calculations using the same data sets is to be carried out and a comparison of these results is to be made against the applicant's submitted program's results.

**6.2 Specific Approval**

- The accuracy of the computational results and actual ship data used by the calculation program for the particular ship on which the program will be installed is to be verified.
- Upon application for data verification, it is to agree on a minimum of four loading conditions, taken from the ship's approved stability information, which are to be used as the test conditions. For ships carrying liquids in bulk, at least one of the conditions is to include partially filled tanks. For ships carrying grain in bulk, one of the grain loading conditions is to include a partially filled grain compartment. Within the test conditions each compartment is to be loaded at least once. The test conditions normally are to cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition and are to include at

least one departure and one arrival condition.

For Type 4 stability software for SRtP, at least three damage cases are to be examined, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.

- The following data, submitted by the applicant, are to be verified whether are consistent with arrangements and most recently approved lightship characteristics of the ship according to current plans and documentation on file, subject to possible further verification on board:
  - Identification of the calculation program including version number;
  - Main dimensions, hydrostatic particulars and, if applicable, the ship profile;
  - The position of the forward and after perpendiculars, and if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks;
  - Ship lightweight and centre of gravity derived from the most recently approved inclining experiment or light weight check;
  - Lines plan, offset tables or other suitable presentation of hull form data if necessary to model the ship;
  - Compartment definitions, including frame spacing, and centres of volume, together with capacity tables (sounding/ullage tables), free surface corrections, if appropriate;
  - Cargo and consumables distribution for each loading condition.

Verification does not absolve the applicant and shipowner of responsibility for ensuring that the information programmed into the onboard computer software is consistent with the current condition of the ship.

## 7 Operation Manual

A simple and straightforward operation manual is to be provided, containing descriptions and instructions, as appropriate, for at least the following:

- installation;
- function keys;
- menu displays;
- input and output data;
- required minimum hardware to operate the software;
- use of the test loading conditions;
- computer-guided dialogue steps;
- list of warnings.

## 8 Installation Testing

To ensure correct working of the computer after the final or updated software has been installed, it is the responsibility of the ship's Master to have test calculations carried out according to the following pattern in the presence of a surveyor:

From the approved test conditions at least one load case (other than light ship) is to be calculated.

Note: Actual loading condition results are not suitable for checking the correct working of the computer.

Normally, the test conditions are permanently stored in the computer.

Steps to be performed:

- Retrieve the test load case and start a calculation run; compare the stability results with those in the documentation.
- Change several items of deadweight (tank weights and the cargo weight) sufficiently to change the draught or displacement by at least 10%. The results are to be reviewed to ensure that they differ in a logical way from those of the approved test condition.
- Revise the above modified load condition to restore the initial test condition and compare the results. Confirm that the relevant input and output data of the approved test condition have been replicated.
- Alternatively, one or more test conditions are to be selected and the test calculation performed by entering all deadweight data for each selected test condition into the program as if it were a proposed loading. The results are to be verified as identical to the results in the approved copy of the test conditions.

## 9 Periodical Testing

It is the responsibility of the ship's Master to check the accuracy of the onboard computer for stability calculations at each Annual Survey by applying at least one approved test condition. If a surveyor is not present for the computer check, a copy of the test condition results obtained by the computer check is to be retained on board as documentation of satisfactory testing for the surveyor's verification.

At each Special Survey this checking for all approved test loading conditions is to be done in presence of the surveyor.

The testing procedure is to be carried out in accordance with paragraph 8.

## 10 Other Requirements

Protection against unintentional or unauthorised modification of programs and data is to be provided.

The program is to monitor operation and activate an alarm when the program is incorrectly or abnormally used.

The program and any data stored in the system are to be protected from corruption by loss of power.

Error messages with regard to limitations such as filling a compartment beyond capacity, or exceeding the assigned load line, etc., are to be included.

# Appendix 3 SLAMMING STRENGTH ASSESSMENT OF BOW BOTTOM STRUCTURES

## 1 General

1.1 General provisions

1.1.1 This Appendix applies to strength assessment of bow bottom structures against slamming for mono-hull ships.

1.1.2 The strength assessment against bottom slamming in this Appendix is based on Ochi-Mottor theory to predict the extreme value of slamming pressures and anti-plastic failure method to evaluate the slamming strength of shell plating, longitudinals and bottom grillage.

1.1.3 The relative motion results required by the procedure to calculate the slamming pressures are to be given by solving three-dimensional linear sea-keeping program.

## 2 Slamming Pressure

### 2.1 Calculation positions

2.1.1 The longitudinal range for direct calculation of slamming pressure at bow bottom structure is to be consistent with the strengthening range specified in 2.15.3 of Chapter 2 in this PART.

### 2.2 Evaluation of loading condition

2.2.1 For the direct strength assessment against bow bottom slamming, the loading condition with a minimum draught forward in navigation is to be identified from the Loading Manual.

### 2.3 Wave environment and calculation conditions

2.3.1 Two-parameter P-M spectrum is adopted to model the wave power spectrum density function, which is given by the following formula:

$$S(\omega) = \frac{124H_S^2}{T_Z^4}\omega^{-5}\exp(-\frac{496}{T_Z^4}\omega^{-4})f_0(\theta)$$

where: $H_s$ — significant wave height, in m;

$T_z$ — mean zero-crossing period, in s;

$\omega$ — angular frequency of wave components, in rad/s;

$f_0(\theta)$ — wave spreading function, obtained from the following formula:

$$f_0(\theta) = \begin{cases} \frac{2}{\pi}\cos^2(\theta-\theta_m), & |\theta-\theta_m| < 90 \\ 0, & \text{Other values} \end{cases}$$

where: $\theta$ — extension wave direction, in degree;

$\theta_m$ — main wave direction, in degree.

2.3.2 The extreme value of slamming pressures is to be determined by short-term prediction approach and the significant wave height $H_s$ is obtained from the following formulae:

$$H_S = \begin{cases} 8 - 0.6\left(\dfrac{300 - L}{100}\right)^{1.5} & \text{m, } L < 300\text{m} \\ 8 + 0.6\left(\dfrac{L - 300}{100}\right)^{1.5} & \text{m, } L \geq 300\text{m} \end{cases}$$

The average zero up-crossing wave period $T_z$ and calculated navigation time $t_n$ are to be selected in accordance with Table 2.3.3 and the intermediate values are to be obtained by interpolation.

**Selection of sea wave conditions** **Table 2.3.2**

| | | | | |
|---|---|---|---|---|
| Significant wave height $H_S$ (m) | 6.0 | 7.0 | 8.0 | 9.0 |
| Average zero up-crossing wave period $T_Z$ (s) | 8.703 | 9.400 | 9.990 | 10.503 |
| Calculated navigation time $t_n$ (h) | 41 | 35 | 35 | 35 |

2.3.3 The speed is to be taken as $0.75V$ and $V$ is defined as 1.1.2.27 of Chapter 1.

2.3.4 The head sea and head oblique sea are to be considered, and interval between wave heading angles is not to be greater than 30 degrees.

2.3.5 The range of wave frequencies is to include 0.2 rad/s to 1.8 rad/s in increments taken as 0.05 rad/s.

2.3.6 Linear rolling damping may be determined by test or empirical formula, if not applicable, 5% of the critical rolling damping value may be taken.

## 2.4 Calculation of slamming pressures

2.4.1 The slamming pressures $P_B$, in kPa, at each section is to be obtained from the following formula:

$$P_B = \frac{1}{2}\rho k_1 C_{ps}\left\{V_0^2 - 2E_v \ln\left[1-(1-\alpha)^{1/n}\right]\right\}$$

where: $\rho$ — density of seawater, in t/m$^3$, taken as 1.025;

$k_1$ — slamming coefficient, to be calculated by the following formula:

$$k_1 = \exp\left(1.377 + 2.419a_1 - 0.873a_3 + 9.624a_5\right)$$

where: $a_1, a_3, a_5$ — the calculated cross-section under draught $d_1$ is mapped to the coefficient of the unit circle from the three parameter conformal transformation equation in the following formula:

$$Z_0 = U(\zeta + a_1\zeta^{-1} + a_3\zeta^{-3} + a_5\zeta^{-5})$$

$d_1$ — $d$/10, in m, where $d$ is the draught;

$Z_0$ — section coordinates;

$\zeta$ — circular coordinates;

$U$ — scale ratio, $U=\dfrac{d_1}{1-a_1+a_3-a_5}$;

$C_{ps}$ — coefficient, taken as 0.44;

$V_0$ — critical slamming speed, in m/s, obtained from the following formulae:

$$V_0=\begin{cases}0.0925\sqrt{L}, & \text{for container ship, passenger ship and vehicle carrier}\\ 0.07\sqrt{L}, & \text{for other ship}\end{cases}$$

$E_v$ — variance of vertical relative velocities for the hull and wave surface of transverse section concerned, determined according to calculation results of spectral analysis in 2.3 of this Appendix;

$\alpha$ — assurance rate, taken as 0.01;

$n$ — number of impacts, replaced by the mean number of impacts $N$ within $t_n$, obtained from the following formula:

$$N=3600\frac{t_n}{2\pi}\sqrt{\frac{E_v}{E_r}}\exp\left\{-\left(\frac{T_f^2}{E_r}+\frac{V_0^2}{E_v}\right)\right\}$$

where:

$E_r$ — variance of vertical relative motions for the hull and wave surface of transverse section concerned, determined according to calculation results of spectral analysis in 2.3 of this Appendix;

$T_f$ — draught of transverse section concerned in assessment condition, in m.

## 3 Strength Assessment

### 3.1 Slamming strength of shell plating

3.1.1 The pressure $P_{cp}$ related to the ultimate capacity of shell plating is to be obtained from the following formula:

$$P_{cp}=\frac{12\mathrm{R}_{eH}t_1^2}{a^2\left[3-\dfrac{2}{\beta^2}\left(\sqrt{1+3\beta^2}-1\right)\right]}\quad \text{MPa}$$

where: $R_{eH}$ — yield stress of material, in N/mm$^2$;

$t_1$ — net thickness of plate panel, in mm;

$a$ — length of the shorter side of the plate panel, in mm;

$b$ — length of the longer side of the plate panel, in mm;

$\beta$ — ratio between the sides, $\beta=b/a$.

3.1.2 When the relationship of the ultimate capacity $P_{cp}$ and the extreme value of slamming pressures $P_B$ is satisfied as below, the shell plating is considered to be with sufficient capacity against slamming:

$$1000\frac{P_{cp}}{P_B} \geqslant 0.75$$

where: $P_B$ —slamming pressures, in kPa, see 2.4.1 of this Appendix.

### 3.2 Slamming strength of shell longitudinals

3.2.1 The pressure $P_{cl}$ related to the ultimate capacity of shell longitudinals is to be obtained from the following formula:

$$P_{cl} = \frac{16R_{eH}W_T}{al^2} \quad \text{MPa}$$

where: $R_{eH}$ — yield stress of material, in N/mm$^2$;

$a$ — spacing of longitudinals, in mm;

$l$ — span of longitudinals, in mm;

$W_T$ — section modulus of longitudinals, including plate flange, in mm$^3$.

3.2.2 When the relationship of the ultimate capacity pressure $P_{cl}$ and the extreme value of slamming pressures $P_B$ is satisfied as below, the shell longitudinals are considered to be with sufficient capacity against slamming:

$$1000\frac{P_{cl}}{P_B} \geqslant 0.75$$

where: $P_B$ —slamming pressures, in kPa, see 2.4.1 of this Appendix.

### 3.3 Slamming strength of bottom grillage

3.3.1 Structural FE model

(1) The longitudinal extent of the model is to include the calculation range as specified in 2.1.1 of this Appendix and at least extend to one web frame distance forward and aft. The transverse extent is to be selected as possible as to reduce the effect of boundary constraints on the response of bottom grillage. For example, the scope between the knuckle to the mid-line of the inner bottom may be selected for oil tankers and similar selection is applicable for other ships.

(2) Selection and meshing of elements are to comply with the requirements of Section 5, Chapter 1 of this PART.

(3) Strength evaluation is to be carried out for all primary members within the extent of strengthening of bottom forward.

(4) When the stress distribution or stiffness of members is affected by the openings on primary members, the methods may be adopted in accordance with the requirements of Section 5, Chapter 1 of this PART.

3.3.2 Boundary constraints

Floors and girders at the boundary of model are to be rigidly fixed.

3.3.3 Loads

According to the principle of slamming, the slamming pressure acts on the floor at the centre girder, the affected area is a square. The length of a side of this square $S_1$ is obtained from the following formula:

$$S_1 = \sqrt{1.1C_bLB \times 10^{-3}} \quad \text{m}$$

The extreme value of slamming pressure at each station of bow bottom will not occur at the same time, therefore the extreme value acting at each station is to be calculated respectively and the

maximum pressure of the bottom grillage is obtained. The distribution of slamming pressures on the floor is to be determined according to the following three situations:

(1) $S_1<S$:

The slamming pressure only acts on one floor, see Figure 3.3.3(1), the force $Q$ acting on the floor in per unit length is to be calculated by the following formula:

$$Q = C_D P_B S_1 \quad \text{kN/m}$$

where: $S$ — spacing of floors, in m;

$P_B$ —slamming pressures, in kPa, see 2.4.1 of this Appendix;

$C_D$ —dynamic slamming coefficient, to be taken as 0.8.

(2) $S<S_1<2S$:

The slamming pressure acts on two floors, see Figure 3.3.3(2), the force $Q$ acting on the floor in per unit length is to be calculated by the following formula:

$$Q = 0.5 C_D P_B S_1 \quad \text{kN/m}$$

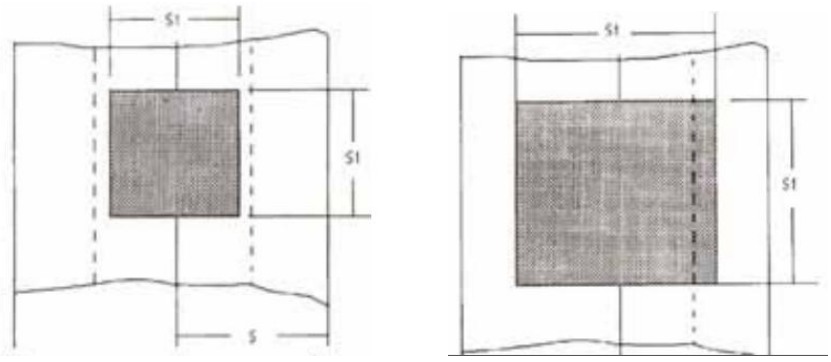
(3) $S_1>2S$:

The slamming pressure acts on three floors, the force $Q_c$ acting on the intermediate floor in per unit length is to be calculated by the following formula:

$$Q_C = C_D P_B S \quad \text{kN/m}$$

The force $Q_s$ acting on the side floor in per unit length is to be calculated by the following formula:

$$Q_S = 0.5 C_D P_B (S_1 - S) \quad \text{kN/m}$$




(1) (2)

**Figure 3.3.3**

3.3.4 Acceptance criteria

Permissible stress of direct calculation of slamming strength for bow bottom grillage is to be determined in accordance with Table 3.3.4.

**Permissible Stress** **Table 3.3.4**

| Member | Positive stress of inner bottom plating $\sigma$ (N/mm$^2$) | Positive stress of outer bottom plating $\sigma$ (N/mm$^2$) | Shear stress $\tau$ (N/mm$^2$) | Equivalent stress $\sigma_e$ (N/mm$^2$) |
|---|---|---|---|---|
| Girder | 122/$K$ | 112/$K$ | 108/$K$ | 180/$K$ |
| Floor | 132/$K$ | 132/$K$ | 98/$K$ | 196/$K$ |

Note: $K$— material factor.

# Appendix 4 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS

## SECTION 1 APPLICATION AND DEFINITIONS

Abbreviation

*EPP* —— Elementary plate panel, as defined in [1.2.3.1];

*PSM* —— Primary supporting member;

*SP* —— Stiffened panel, as defined in [1.2.3.3];

*UP* —— Unstiffened panel, as defined in[1.2.3.3].

### 1.1 Application

#### 1.1.1 General Requirements

1.1.1.1 Relevant unified requirements concerning strength of ships

This Appendix establishes a general buckling assessment procedure as illustrated in Figure 1.1.1.1, and is to be applied in conjunction with Section 20 of Chapter 2 for hatch cover structures. The Section 20 of Chapter 2 is referred to as Relevant UR-S hereafter in this Appendix.

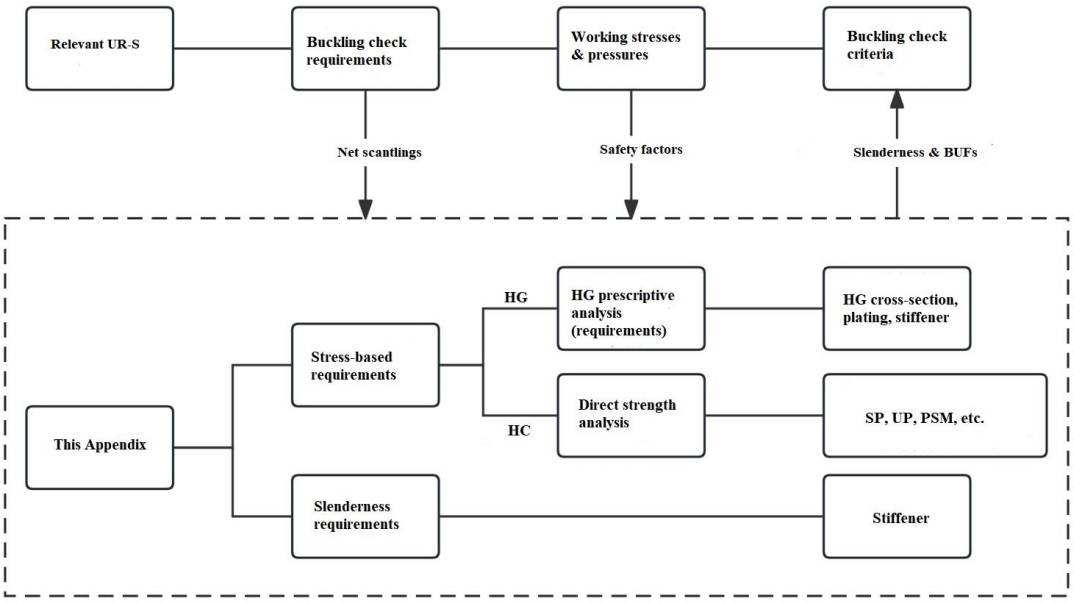



Figure 1.1.1.1 Overview of applying this UR in conjunction with Relevant UR-S

#### 1.1.2 Application of this Appendix

1.1.2.1 Sections of this Appendix and application description

The buckling checks are to be performed according to:

(1) Section 1 for general definitions regarding buckling capacity, allowable buckling utilisation factors and buckling check criteria.

(2) Section 2 for the slenderness requirements of longitudinal and transverse stiffeners.

(3) Section 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses.
(4) Section 4 for direct strength analysis (usually by finite element method) buckling requirements of hatch cover structural members including plates, stiffeners and primary supporting members.
(5) Section 5 for the determination of buckling capacities of plate panels, stiffeners, primary supporting members and column structures.

1.1.2.2 Buckling assessment with this Appendix

For the buckling assessment of a ship hull girder, a hatch cover or other structural components, the slenderness requirements as defined in Section 2 and the buckling requirements as defined in Section 3 or Section 4 are to be checked as per the requirements of the applicable Relevant UR-S.

1.1.2.3 Alternative methods

This Appendix contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this Appendix, such as a whole plate structure with stiffeners in two directions (i.e., a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used with the consent of CCS.

## 1.2 Terminology and Assumptions

### 1.2.1 Buckling

1.2.1.1 Buckling strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behaviour in [1.2.1.2] gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

1.2.1.2 Buckling behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally its positive elastic post-buckling effect can be utilized.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilisation levels.

### 1.2.2 Net Scantling Approach

1.2.2.1 General requirements

Unless otherwise specified, all the scantling requirements, including slenderness requirements, in this Appendix are based on net scantlings obtained by removing full corrosion addition $t_c$ from the gross offered thicknesses.

1.2.2.2 Corrosion addition

Corrosion addition $t_c$ referred to in this Appendix is defined in the Relevant UR-S.

1.2.2.3 Stress calculation models

The structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the Relevant UR-S.

### 1.2.3 Structural Idealisation

1.2.3.1 Elementary plate panel (EPP)

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 1.2.3.1.

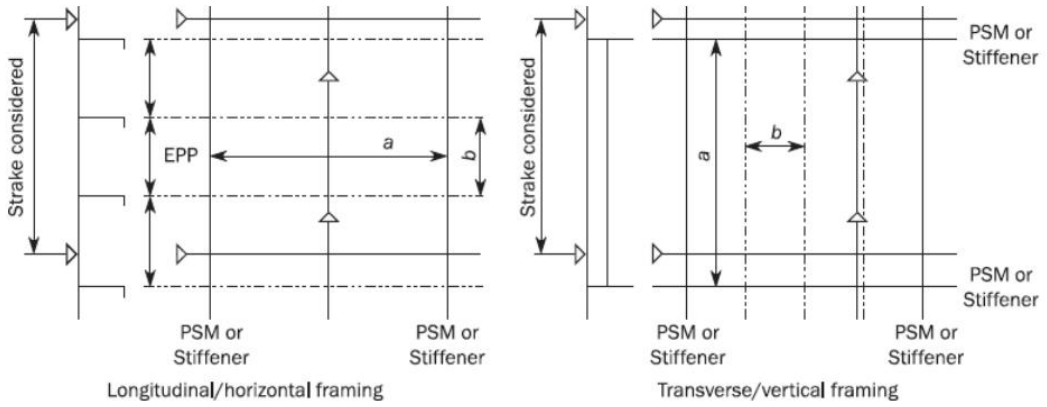



Figure 1.2.3.1 Elementary plate panel (EPP) definition

1.2.3.2 Standard types of stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in Figure 1.2.3.2(1), which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealized to one of the typical types in Figure 1.2.3.2(1) for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in Figure 1.2.3.2(2).

Unless otherwise specified, the full span or full length *l*, in mm, of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members.

Symbolic dimensions of the cross-sections are as below:

$b_1$ —— Width of the attached plate enclosed by the U-type stiffener, in mm, as shown in Figure 1.2.3.2(2);

$b_2$ —— Width of the attached plate between adjacent U-type stiffeners, in mm, as shown in Figure 1.2.3.2(2);

$b_f$ —— Width of the flange or face plate of the stiffener, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

$b_{f\text{-}out}$ —— Maximum distance, in mm, from mid thickness of the web to the flange edge, in mm, as shown in Figure 1.2.3.2(1);

$d_f$ —— Breadth of the extended part of the flange for L2profiles, in mm, as shown in Figure 1.2.3.2(1);

$e_f$ —— Distance from attached plating to centre of flange, in mm, as shown in Figure 1.2.3.2(1). For its detailed definition, refer to Section 5, Symbols;

$h_w$ —— Depth of stiffener web, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

$t_f$ —— Net flange thickness, in mm;

$t_p$ —— Net thickness of plate, in mm;

$t_w$ —— Net web thickness, in mm.

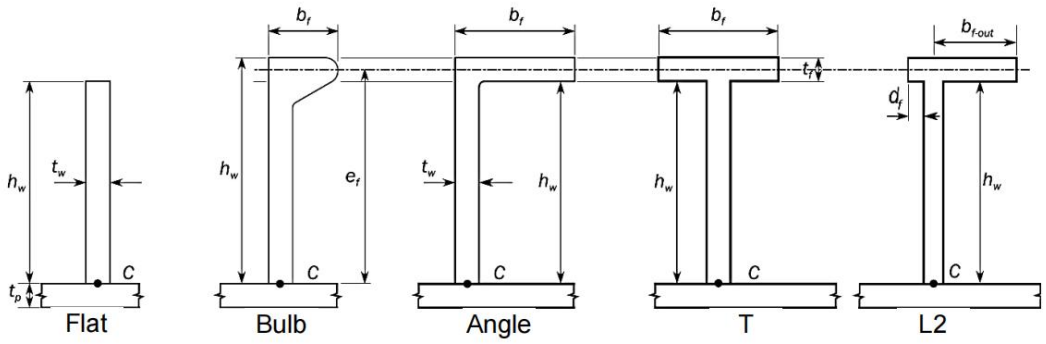



Figure 1.2.3.2(1) Dimensions of typical stiffener cross sections

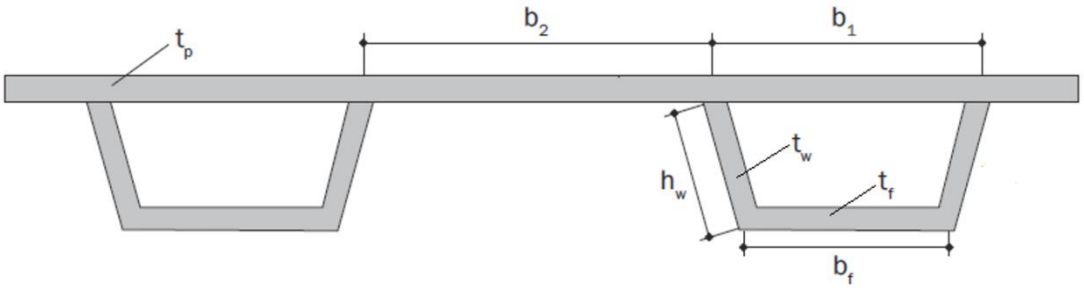


Figure 1.2.3.2(2) Dimensions of a U-type stiffener cross section

1.2.3.3 Stiffened panel (SP) and unstiffened panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (SP), so as to be able to consider both of its local and global buckling modes.

However, for an EPP, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it is to be modelled as an unstiffened panel (UP).

### 1.2.4 Sign Convention

1.2.4.1 Stresses

In this Appendix, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

## 1.3 Assessment Methods and Acceptance Criteria

### 1.3.1 Assessment Methods

1.3.1.1 Method A and Method B

The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

(1) Method A: All the edges of the EPP are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.

(2) Method B: The edges of the EPP are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

1.3.1.2 SP-A、SP-B、UP-A and UP-B models

For the buckling assessment of the stiffened panel (SP) and unstiffened panel (UP) structural models defined in [1.2.3.3], with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

(1) SP-A: a stiffened panel with application of Method A.

(2) SP-B: a stiffened panel with application of Method B.

(3) UP-A: an unstiffened panel with application of Method A.

(4) UP-B: an unstiffened panel with application of Method B.

### 1.3.2 Buckling Utilisation Factor

1.3.2.1 The utilisation factor, $\eta$, is defined as the ratio between the applied loads and the corresponding buckling capacity.

1.3.2.2 For combined loads, the utilisation factor, $\eta_{act}$, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Figure 1.3.2.2, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

where:

$W_{act}$ —— Equivalent applied stress. The actual applied stresses are given in Section 3 and Section 4 respectively for buckling assessment by prescriptive and direct strength analysis;

$W_U$ —— Equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in Section 5;

$\gamma_c$ —— Stress multiplier factor at failure.

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e., when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Figure 1.3.2.2 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to $\sigma_x$ and $\sigma_y$ stresses.

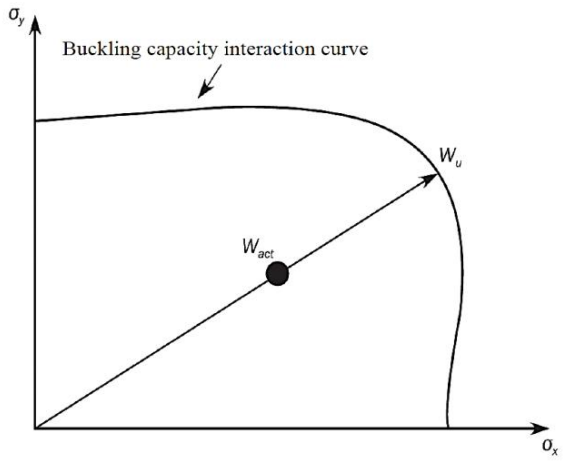



Figure 1.3.2.2 Illustration of buckling capacity and buckling utilisation factor

### 1.3.3 Allowable Buckling Utilisation Factor

1.3.3.1 The allowable buckling utilisation factor $\eta_{all}$ is to be taken according to the Relevant UR-S.

### 1.3.4 Buckling Acceptance Criteria

1.3.4.1 A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

$\eta_{act}$ —— Buckling utilisation factor based on the applied stress, defined in [1.3.2.2];

$\eta_{all}$ —— Allowable buckling utilisation factor, as defined in [1.3.3.1].

## SECTION 2 SLENDERNESS REQUIREMENTS

**Symbols**

For symbols not defined in this section, refer to Section 1, [1.2.3.2].

$R_{eH}$ —— Specified minimum yield stress of the structural member being considered, in N/mm$^2$.

### 2.1 General Requirements

#### 2.1.1 Introduction

2.1.1.1 The stiffener elements except for U-type stiffeners are to comply with the applicable slenderness and proportion requirements given in this Section.

### 2.2 Stiffeners

### 2.2.1 Proportions of Stiffeners

2.2.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

(1) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

(2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

$C_w, C_f$ —— Slenderness coefficients given in Table 2.2.1.1.

**Slenderness Coefficient** **Table 2.2.1.1**

| Type of Stiffener | $C_w$ | $C_f$ |
|---|---|---|
| Angle and L2 bars | 75 | 12 |
| T-bars | 75 | 12 |
| Bulb flats | 45 | - |
| Flat bars | 22 | - |

If requirement (2) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in Table 2.2.1.1, and the edge stiffener can be assessed as a flat bar stiffener according to [2.2.1.1]. The requirement to flange in [2.2.1.2] shall still apply.

2.2.1.2 Net dimensions of angle and T-bars

The total flange breadth, $b_f$, in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.2h_w$$

## 2.3 Primary Supporting Members

### 2.3.1 Proportions and Stiffness

2.3.1.1 Proportions of web plate and flange

The scantlings of webs and flanges of primary supporting members are to comply with the relevant requirements of [4.1], Section 2, Chapter 8, PART NINE of the Rules.

# SECTION 3 BUCKLING REQUIREMENTS FOR HULL GIRDER PRESCRIPTIVE ANALYSIS

**Symbols**

$\eta_{all}$ : Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

LCP：Load calculation point, as defined in [3.1.2.1].

## 3.1 General Requirements

### 3.1.1 Introduction

3.1.1.1 This Section applies to plate panels including plane and curved plate panels, stiffeners and corrugation of longitudinal corrugated bulkheads subject to hull girder compression and shear stresses.

3.1.1.2 The ship longitudinal extent where the buckling check is performed for structural elements subject to hull girder stresses is to be in accordance with the Relevant UR-S.

3.1.1.3 Design load sets: The buckling check is to be performed for all design load sets corresponding to the design loading conditions defined in the Relevant UR-S with the most unfavourable pressure combinations.

For each design load set, for all static and dynamic load cases, the lateral pressure is to be determined at the load calculation point defined in [3.1.2.1], and is to be applied together with the hull girder stress combinations defined in the Relevant UR-S.

### 3.1.2 Definitions

3.1.2.1 Load calculation point

The load calculation points (LCP) for both elementary plate panels (EPP) and stiffeners are defined as follows:

(1) LCP for hull girder stresses of EPP

The hull girder stresses for EPP are to be calculated at the load calculation points defined in Table 3.1.2.1.

**Load calculation points (LCP) coordinates for plate buckling assessment**

**Table 3.1.2.1**

| LCP coordinates | Hull girder bending stress | | Hull girder shear stress |
|---|---|---|---|
| | Non horizontal plating | Horizontal plating | |
| *x* coordinate | Mid-length of the EPP | | |
| *y* coordinate | Both upper and lower ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1)) | Outboard and inboard ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1)) | Mid-point of EPP (point B in Figure 3.1.2.1(1)) |
| *z* coordinate | Corresponding to *x* and *y* values | | |

(2) LCP for hull girder stresses of longitudinal stiffeners

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

① at the mid length of the considered stiffener;

② at the intersection point between the stiffener and its attached plate.

(3) LCP for pressure of horizontal stiffeners

The load calculation point for the pressure is located at:

① middle of the full length, *l*, of the considered stiffener;

② the intersection point between the stiffener and its attached plate.

(4) LCP for pressure of non-horizontal stiffeners

The lateral pressure, *P* is to be calculated as the maximum between the value obtained at middle of the full length, *l*, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level;

$P = \frac{l_1}{l}\frac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level.

where: $l_1$ —— Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level;

$p_U$ , $p_L$ ——Lateral pressure at the upper and lower end of the vertical stiffener span, $l$, respectively.

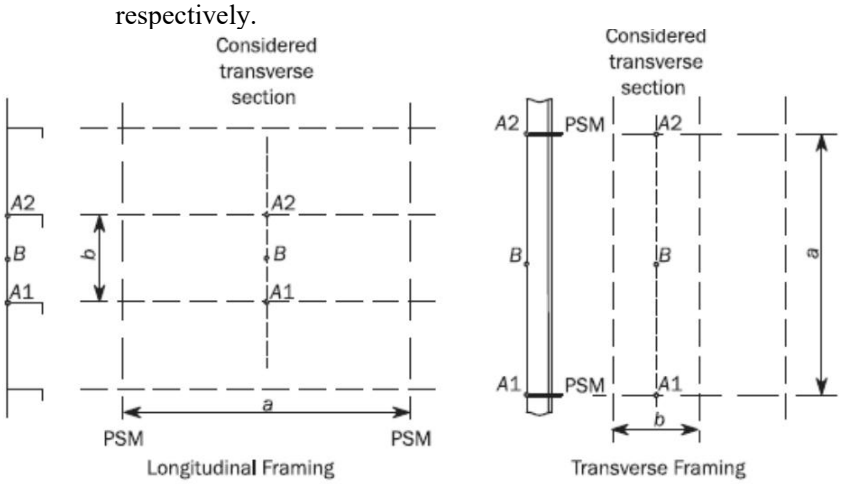



Figure 3.1.2.1(1) LCP for plate buckling assessment (PSM means the primary supporting members)

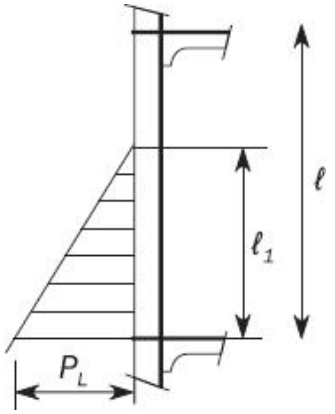



Figure 3.1.2.1(2) Definition of pressure for vertical stiffeners

### 3.1.3 Equivalent plate panels

3.1.3.1 Longitudinal stiffening with varying plate thickness

In longitudinal stiffening arrangement, when the plate thickness varies over the width $b$, of a plate panel (EPP), the buckling check is to be performed for an equivalent plate panel width,combined with the smaller plate thickness, $t_1$. The width of this equivalent plate panel, $b_{eq}$, in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2(\frac{t_1}{t_2})^{1.5}$$

where: $l_1$——Width of the part of the plate panel with the smaller plate thickness, $t_1$, in mm, as defined in Figure 3.1.3.1;

$l_2$—— Width of the part of the plate panel with the greater plate thickness, $t_2$, in mm, as defined in Figure 3.1.3.1.

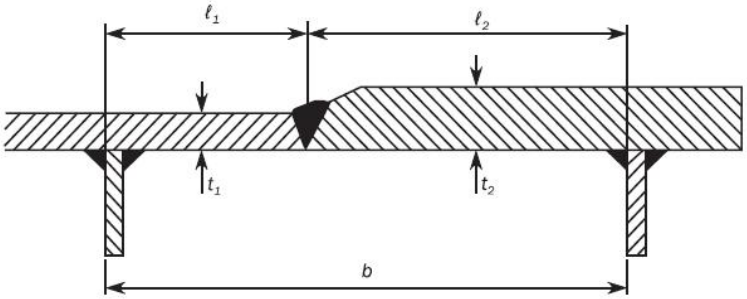



Figure 3.1.3.1 Plate thickness change over the width

3.1.3.2 Transverse stiffening with varying plate thickness

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

3.1.3.3 Plate panel with different materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

## 3.2 Buckling Criteria

### 3.2.1 Overall Stiffened Panel

3.2.1.1 The buckling strength of overall stiffened panels is to satisfy the following criterion:

$$\eta_{overall} \le \eta_{all}$$

where: $\eta_{overall}$ ——Maximum overall buckling utilisation factor as defined in Section 5, [5.2.1].

### 3.2.2 Plates

3.2.2.1 The buckling strength of elementary plate panels is to satisfy the following criterion:

$$\eta_{plate} \le \eta_{all}$$

where: $\eta_{plate}$ ——Maximum plate buckling utilisation factor as defined in Section 5, [5.2.2] where SP-A model is to be used.

For the determination of $\eta_{plate}$ of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Section 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean $\sigma_y$ stress and $\varphi_y = 1$.

### 3.2.3 Stiffeners

3.2.3.1 The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$$\eta_{stiffener} \le \eta_{all}$$

where：$\eta_{stiffener}$ ——Maximum stiffener buckling utilisation factor as defined in Section 5, [5.2.3].

Note 1: This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in [3.2.1], is satisfied.

Note 2: The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.

### 3.2.4 Vertically Corrugated Longitudinal Bulkheads

3.2.4.1 The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$$\eta_{shear} \le \eta_{all}$$

where: $\eta_{shear}$ —— Maximum shear buckling utilisation factor, defined as

$$\eta_{shear} = \frac{\tau_{bhd}}{\tau_c} ;$$

$\tau_{bhd}$ ——Shear stress, in N/mm$^2$, in the bulkhead taken as the hull girder shear stress defined in the Relevant UR-S;

$\tau_c$ —— Shear critical stress, in N/mm$^2$, as defined in Section 5, [2.2.3].

### 3.2.5 Horizontally Corrugated Longitudinal Bulkheads

3.2.5.1 Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 3.2.5.1) is to satisfy the following criterion:

$$\eta_{column} \leq \eta_{all}$$

where: $\eta_{column}$ —— Overall column buckling utilisation factor, as defined in Section 5, [5.3.1].

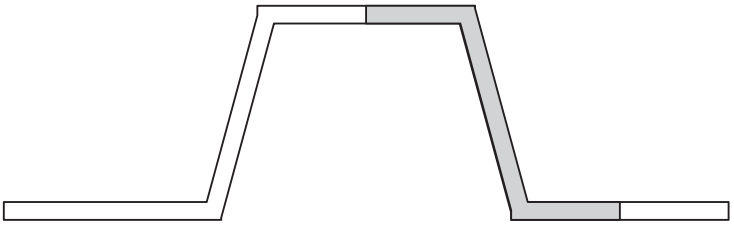


Figure 3.2.5.1 Single corrugation

## SECTION 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS OF HATCH COVERS

**Symbols**

$R_{eH_P}$——Yield stress of the plate panel, as defined in [4.2.1.3];

$R_{eH_S}$——Yield stress of the stiffener, as defined in [4.2.1.3];

$\alpha$—— Aspect ratio of the plate panel as defined in the Symbol list of Section 5;

$\eta_{all}$ ——Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

### 4.1 General Requirements

#### 4.1.1 Introduction

4.1.1.1 The requirements of this Section apply to the buckling assessment of hatch cover structural members based on direct strength analysis (usually by finite element method) and subjected to normal stress, shear stress and lateral pressure.

4.1.1.2 All structural elements in the direct strength analysis carried out according to the Relevant UR-S are to be assessed individually. The buckling checks are to be performed for the following structural elements:

- Stiffened and unstiffened panels.
- Web plate in way of openings.

### 4.2 Stiffened and Unstiffened Panels

#### 4.2.1 General Requirements

4.2.1.1 The plate panel of a hatch cover structure is to be modelled as stiffened panel or unstiffened panel, with either Method A or Method B as defined in Section 1, [1.3.1.1] to be used

for the calculation of the plate buckling capacity, which in combination is also equivalent to use the buckling assessment models defined in Section 1, [1.3.1.2].

4.2.1.2 Average thickness of plate panel

For FE analysis, where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

where: $A_i$——Area of the *i*-th plate element;

$t_i$ ——Net thickness of the *i*-th plate element;

$n$ ——Number of finite elements defining the buckling plate panel.

4.2.1.3 Yield stress of the plate panel and stiffener

The panel yield stress $R_{eH_P}$ is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

The stiffener yield stress $R_{eH_S}$ is taken as the minimum value of the specified yield stress of the elements within the stiffener.

**4.2.2 Stiffened Panels**

4.2.2.1 For a stiffened panel (SP), each stiffener with attached plate is to be idealized as a stiffened panel model of the extent defined in the Relevant UR-S.

4.2.2.2 If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

4.2.2.3 The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

**4.2.3 Unstiffened Panels**

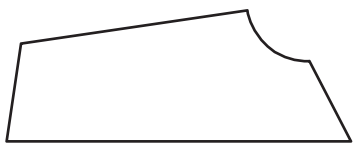
4.2.3.1 Irregular plate panel

In way of web frames, horizontal girders and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [4.2.3.2] for irregular geometry and [4.2.3.3] for triangular geometry and to comply with buckling assessment.

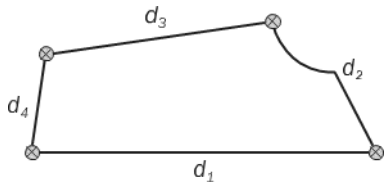
4.2.3.2 Equivalent EPP of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.

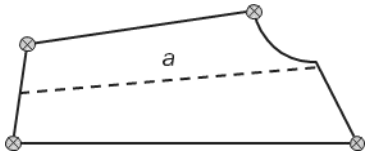


(2) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight-line segments between the end points.




(3) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$.

(4) A line joins the middle points of the chosen opposite edges (i.e. a mid-point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, $a$, measured from one end point.



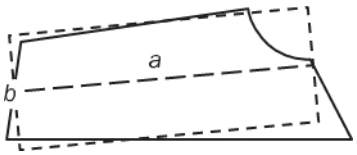

(5) The length of shorter side, $b$, in mm, is to be taken as:

$$b = \frac{A}{a}$$

where:

$A$ —— Area of the plate in $mm^2$;

$a$ —— Length defined in (4), in mm.

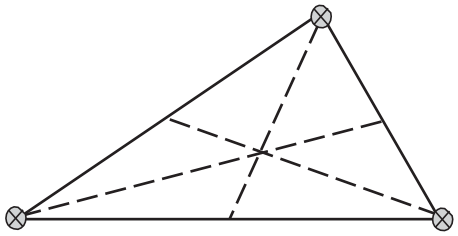



(6) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

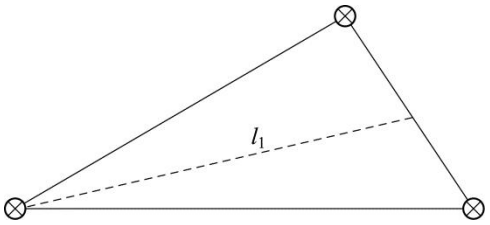
4.2.3.3 Modeling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) Medians are constructed as shown below:



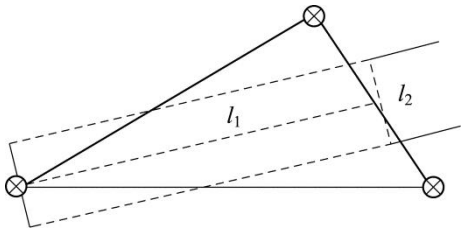
(2) The longest median is identified. This median the length of which is $l_1$, in mm, defines the longitudinal direction for the capacity model.




(3) The width of the model, $l_2$, in mm, is to be taken as:

$$l_2 = \frac{A}{l_1}$$

where: $A$ —— Area of the plate, in mm$^2$.




(4) The lengths of shorter side, *b,* and of the longer side, *a*, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$$a = l_1 C_{tri}$$

where: $C_{tri} = 0.4\frac{l_2}{l_1} + 0.6$

(5) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

**4.2.4 Reference Stress**

4.2.4.1 The stress distribution is to be taken from the direct strength analysis according to the Relevant UR-S and applied to the buckling model.

4.2.4.2 For FE analysis, the reference stresses are to be calculated using the stress-based reference stresses as defined in Section 6.

**4.2.5 Lateral Pressure**

4.2.5.1 The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

4.2.5.2 Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, in N/mm$^2$, is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

where:

$A_i$—— Area of the *i*-th plate element, in mm$^2$;

$P_i$—— Lateral pressure of the *i*-th plate element, in N/mm$^2$;

$n$—— Number of the finite elements in the buckling panel.

### 4.2.6 Buckling Criteria

4.2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

where: $\eta_{UP-A}$ —— Maximum buckling utilisation factor of plate, calculated according to Method A as defined in Section 5, [5.2.2].

4.2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$$\eta_{UP-B} \leq \eta_{all}$$

where: $\eta_{UP-B}$ —— Maximum buckling utilisation factor of plate, calculated according to Method B as defined in Section 5, [5.2.2].

4.2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$$\eta_{SP-A} \leq \eta_{all}$$

where: $\eta_{SP\text{-}A}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisaiton factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation factor $\eta_{plate}$ calculated according to Method A as defined in Section 5 [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$$\eta_{SP-B} \leq \eta_{all}$$

where: $\eta_{SP\text{-}B}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation $\eta_{plate}$ calculated according to Method B as defined in Section 5, [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the

stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$$\eta_{opening} \leq \eta_{all}$$

where: $\eta_{opening}$ —— Maximum web plate utilisation factor in way of openings, calculated with the definition in Section 1, [1.3.2.2] and the stress multiplier factor at failure $\gamma_c$ which can be calculated following the requirements in Section 5, [5.2.4].

## SECTION 5 BUCKLING CAPACITY

**Symbols**

$A_p$ —— Net sectional area of the stiffener attached plating, in mm$^2$, taken as:

$A_p = st_p$;

$A_s$ —— Net sectional area of the stiffener without attached plating, in mm$^2$;

$a$ —— Length of the longer side of the plate panel, in mm;

$b$ —— Length of the shorter side of the plate panel, in mm;

$b_{eff}$ —— Effective width of the attached plating of a stiffener, in mm, as defined in [5.2.3.5];

$b_{eff1}$ —— Effective width of the attached plating of a stiffener, in mm, without the shear lag effective taken as:

(1) For $\sigma_x > 0$,

① For prescriptive assessment:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

② For FE analysis:

$$b_{eff1} = C_x b$$

(2) For $\sigma_x \leq 0$,

$$b_{eff1} = b;$$

$b_f$ —— Breadth of the stiffener flange, in mm;

$b_1, b_2$ —— Width of plate panel on each side of the considered stiffener, in mm. For stiffened panels fitted with U-type stiffeners, $b_1$ and $b_2$ are as defined in Section 1, Figure 1.2.3.2(2);

$C_{x1}, C_{x2}$ —— Reduction factor defined in Table 5.2.2.3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1;

$d$ —— Length of the side parallel to the cylindrical axis of the cylinder corresponding to the curved plate panel as shown in Table 5.2.2.6, in mm;

$e_f$ —— Distance from attached plating to center of flange, in mm, as shown in Section 1, Figure 1.2.3.2(1), to be taken as:

$e_f = h_w$ for flat bar profile

$e_f = h_w - 0.5t_f$ for bulb profile

$e_f = h_w + 0.5t_f$ for angle, L2 and T profiles.

$F_{long}$ —— Coefficient defined in [5.2.2.4];

$F_{tran}$ —— Coefficient defined in [5.2.2.5];

$h_w$ —— Depth of stiffener web, in mm, as shown in Section 1, Figure 1.2.3.2(1);

$l$ —— Span, in mm, of stiffener equal to spacing between primary supporting members of span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell;

$R$ —— Radius of curved plate panel, in mm;

$R_{eH_P}$ —— Specified minimum yield stress of the plate, in N/mm$^2$;

$R_{eH_S}$ —— Specified minimum yield stress of the stiffener, N/mm$^2$;

$S$ —— Partial safety factor, unless otherwise specified in the Relevant UR-S, to be taken as 1.0;

$t_p$ —— Net thickness of plate panel, in mm;

$t_w$ —— Net stiffener web thickness, in mm;

$t_f$ —— Net flange thickness, in mm;

*x-axis* —— Local axis of a rectangular buckling panel parallel to its long edge;

*y-axis* —— Local axis of a rectangular buckling panel perpendicular to its long edge;

$\alpha$ —— Aspect ratio of the plate panel, defined in Table 5.2.2.3, to be taken as: $\alpha = \frac{a}{b}$;

$\beta$ —— Coefficient taken as: $\beta = \frac{1-\psi}{\alpha}$;

$\omega$ —— Coefficient taken as: $\omega = min\,(3, \alpha)$;

$\sigma_x$ —— Normal stress applied on the edge along *x*-axis of the buckling panel, in N/mm$^2$;

$\sigma_y$ —— Normal stress applied on the edge along *y*-axis of the buckling panel, in N/mm$^2$;

$\sigma_1$ —— Maximum normal stress along a panel edge, in N/mm$^2$;

$\sigma_2$ —— Minimum normal stress along a panel edge, in N/mm$^2$;

$\sigma_E$ —— Elastic buckling reference stress, in N/mm$^2$, to be taken as:

(1) For the application of the limit state of plane plate panels according to [5.2.2.1]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

(2) For the application of the limit state of curved plate panels according to [5.2.2.6]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2;$$

$\tau$ —— Applied shear stress, in N/mm$^2$;

$\tau_c$ —— Buckling strength in shear, in N/mm$^2$;

$\psi$ —— Edge stress ratio to be taken as: $\psi = \frac{\sigma_2}{\sigma_1}$;

$\gamma$ —— Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$;

$\gamma_c$ —— Stress multiplier factor at failure;

$\gamma_{GEB}$ —— Stress multiplier factor of global elastic buckling capacity.

## 5.1 General Requirements

### 5.1.1 Introduction

5.1.1.1 This Section contains the methods for determination of the buckling capacities of plate panels, stiffeners, primary supporting members and columns.

5.1.1.2 For the application of this Section, the stresses $\sigma_x$, $\sigma_y$ and $\tau$ applied on the structural members are defined in:

(1) Section 3 for hull girder prescriptive buckling requirements.

(2) Section 4 for direct strength analysis buckling requirements of hatch covers.

5.1.1.3 Buckling capacity

The buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [5.2.1.1], [5.2.2.1] and [5.2.3.4] of this Section are equal to 1.0, respectively.

5.1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

5.1.1.5 Lateral pressure

The lateral pressure is to be applied and considered as constant for the calculation of buckling capacities as defined in [5.1.1.3].

## 5.2 Buckling Capacity of Plate Panels

### 5.2.1 Overall Stiffened Panels

5.2.1.1 The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [5.2.3.4]:

$$\frac{\gamma_c}{\gamma_{GEB}} = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{overall} = \frac{1}{\gamma_c}$$

where: the stress multiplier factor of global elastic buckling capacity, $\gamma_{GEB}$, are to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and ($\sigma_x \leq 0$ or $\sigma_y \leq 0$) .

where: $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are stress multiplier factors of the global elastic buckling capacity for different load combinations as defined in [5.2.1.2], [5.2.1.3] and [5.2.1.4], respectively. For the calculation of $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$, neither $\sigma_x$ nor $\sigma_y$ are to be taken less than 0.

$\sigma_x, \sigma_y$ —— Applied normal stress to the plate panel, in N/mm$^2$, to be taken as defined in

[5.2.2.7];

$\tau$ —— Applied shear stress, in N/mm$^2$, to be taken as defined in [5.2.2.7].

5.2.1.2 The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{\left[D_{11}L_{B2}^4 + 2(D_{12}+D_{33})n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4\right]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

$N_x$—— Load per unit length applied on the edge along *x*-axis of the stiffened panel, in N/mm, taken as

$N_x = \sigma_{x,av}(A_p + A_s)/s$

For stiffened panels fitted with U-type stiffeners, stiffener spacing *s* is taken as:

$s = b_1 + b_2$

Where $b_1$ and $b_2$ are as defined in Figure 5.3.1.4;

$N_y$—— Load per unit length applied on the edge along *y*-axis of the stiffened panel, in 方 N/mm, taken as:

$N_y = c\sigma_y t_p$;

$L_{B1}$—— Stiffener span, in mm, distance between primary supporting members, i.e.

$L_{B1} = l$;

$L_{B2}$—— Width of stiffened panel between stiffened panels, in mm, taken as 6 times of the stiffer spacing, i.e. $L_{B2} = 6s$;

*n*—— Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be taken as the smallest value larger than 0.

*c*—— Factor taking into account the normal stress distribution in the panel boundaries acting perpendicular to the stiffener's axis:

$c = 0.5(1+\Psi)$ for $0 \leq \Psi \leq 1$;

$c = \frac{1}{2(1-\Psi)}$ for $\Psi < 0$ ;

$\Psi$—— Edge stress ratio for case 2 according to Table 5.3.1.3;

$\sigma_{x,av}$—— Average stress, in MPa, for both plate and stiffener after Poisson correction, taken as:

$\sigma_{x,av} = \sigma_x - \nu c\sigma_y A_s/(A_p + A_s) \geq 0$ for $\sigma_x > 0$ and $\sigma_y > 0$

$\sigma_{x,av} = \sigma_x$ for $\sigma_x \leq 0$ or $\sigma_y \leq 0$;

$D_{11}, D_{12}, D_{22}, D_{33}$ —— Bending stiffness coefficients, in N·mm, of the stiffened panel, defined in general as:

$$\left.\begin{aligned} D_{11} &= \frac{EI_{eff}10^4}{s} \\ D_{12} &= \frac{Et_p^3\nu}{12(1-\nu^2)} \\ D_{22} &= \frac{Et_p^3}{12(1-\nu^2)} \\ D_{33} &= \frac{Et_p^3}{12(1+\nu)} \end{aligned}\right\}$$

For stiffened panels fitted with U-type stiffeners, $D_{12}$ and $D_{22}$ are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-\nu^2)}\left[1.2 + 4.8 \times Min\left(1.0,\ \frac{b_1^2}{h_w(b_1+b_2)}\right) \times Min\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = \nu D_{22}$$

$h_w$—— Breadth of U-type stiffener web as defined in Figure 5.3.1.4;

$I_{eff}$——Moment of inertia, in cm$^4$, of the stiffener including the effective width of the attached plating, same as I defined in [5.2.3.4].

5.2.1.3 The stress multiplier factor $\gamma_{GEB,\tau}$, for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}}\left[8.125 + 5.64\sqrt{\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}} - 0.6\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}\right] \quad \text{for } D_{11}D_{22} \geq (D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12}+D_{33})}}{(L_{B1}/2)^2 N_{xy}}\left[8.3 + 1.525\frac{D_{11}D_{22}}{(D_{12}+D_{33})^2} - 0.493\frac{D_{11}^2 D_{22}^2}{(D_{12}+D_{33})^4}\right] \quad \text{for } D_{11}D_{22} < (D_{12}+D_{33})^2$$

where: $N_{xy} = \tau t_p$

5.2.1.4 The stress multiplier factor$\gamma_{GEB,bi+\tau}$, for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2}{\gamma_{GEB,\tau}}^2\left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{{\gamma_{GEB,bi}}^2} + 4\frac{1}{{\gamma_{GEB,\tau}}^2}}\right]$$

where: $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [5.2.1.2] and [5.2.1.3], respectively.

### 5.2.2 Plates

5.2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{\frac{e_0}{2}}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{\frac{e_0}{2}} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|S}{\tau_c}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c2}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cy}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c} = 1$$

with:

$$\gamma_c = Min\,(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

and the corresponding buckling utilisation factor defined as:

$$\eta_{plate} = \frac{1}{\gamma_c}$$

where:

$\sigma_x, \sigma_y$ —— Applied normal stress to the plate panel, in N/mm$^2$, to be taken as defined in [5.2.2.7];

$\tau$ —— Applied shear stress to the plate panel, in N/mm$^2$;

$\sigma_{cx}$ —— Ultimate buckling stress, in N/mm$^2$, in direction parallel to the longer edge of the buckling panel as defined in [5.2.2.3];

$\sigma_{cy}$ —— Ultimate buckling stress, in N/mm$^2$, in direction parallel to the shorter edge of the buckling panel as defined in [5.2.2.3];

$\tau_c$ —— Ultimate buckling shear stress, in N/mm$^2$, as defined in [5.2.2.3];

$\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4}$ Stress multiplier factors at failure for each of the above different limit states. $\gamma_{c2}$ and $\gamma_{c3}$ are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.

$B$ —— Coefficient given in Table 5.2.2.1;

$e_0$ —— Coefficient given in Table 5.2.2.1;

$\beta_p$ —— Plate slenderness parameter taken as: $\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$.

Definition of coefficients of $B$ and $e_0$ Table 5.2.2.1

| **Applied stress** | $\boldsymbol{B}$ | $\boldsymbol{e_0}$ |
|---|---|---|
| $\sigma_x \geq 0$ and $\sigma_y \geq 0$ | $0.7 - 0.3\,\beta_p/\alpha^2$ | $2/\beta_p^{0.25}$ |
| $\sigma_x < 0$ or $\sigma_y < 0$ | 1.0 | 2.0 |

5.2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where: $K$——Buckling factor, as defined in Table 5.2.2.3 and Table 5.2.2.6.

5.2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm$^2$, are to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm$^2$, is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where: $C_x, C_y, C_\tau$ ——Reduction factors, as defined in Table 5.2.2.3.

For the 1st Equation of [5.2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to be taken as :

$$C_x = C_y = C_\tau = 1$$

For other cases:

(1) For SP-A and UP-A, $c_1$ is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(2) For SP-B and UP-B, $c_1$ is calculated according to Table 5.2.2.3 by using

$$c_1 = 1$$

(3) For vertically stiffened single side skin of bulk carrier, $c_1$ is calculated according to Table 5.2.2.3 by using

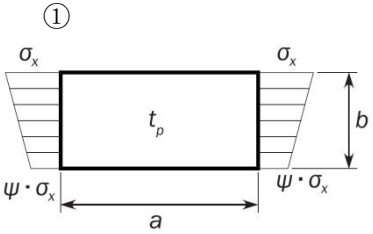
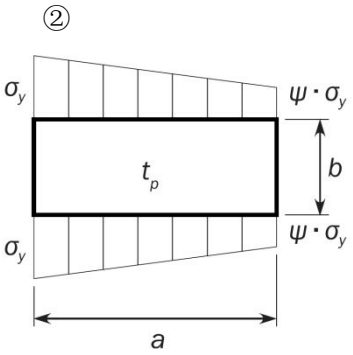
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(4) For corrugation of corrugated bulkheads, $c_1$ is calculated according to Table 5.2.2.3 by using

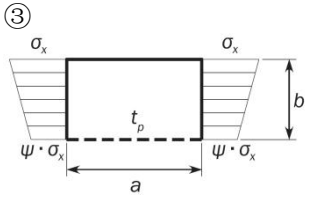
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

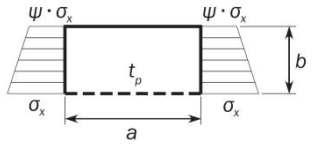
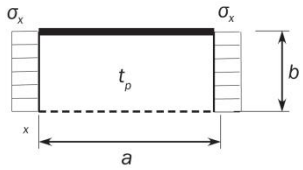
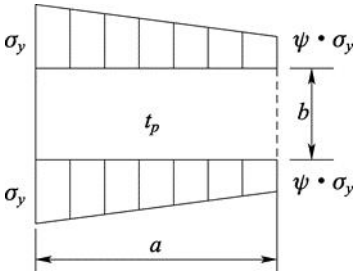
The boundary conditions for plates are to be considered as simply supported, see cases in ①, ② and ⑮ of Table 5.2.2.3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 5.2.2.3 with the consent of CCS.

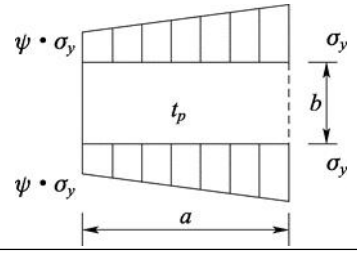
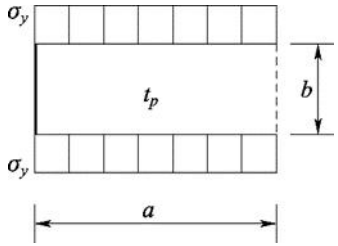
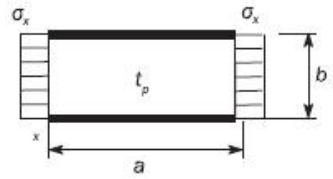
Buckling factor and reduction factor plane plate panels Table 5.2.2.3

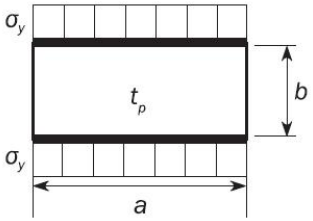
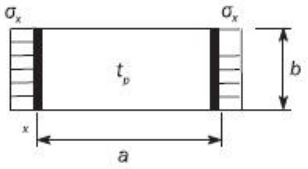
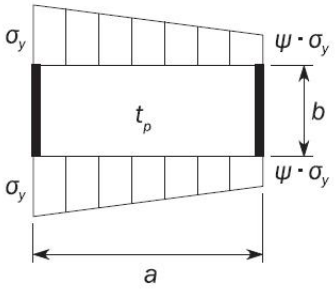
| Case | **Stress ratio $\psi$** | **Aspect ratio $\alpha$** | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|---|
| ①   | $1\geq\psi\geq 0$ | $K_x = F_{long}\dfrac{8.4}{\psi+1.1}$ | | When $\sigma_x \leq 0$, $C_x = 1$;<br>When $\sigma_x > 0$,<br>$C_x = 1$ for $\lambda \leq \lambda_c$<br>$C_x = c\left(\frac{1}{\lambda}-\frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$<br>where:<br>$c = (1.25-0.12\psi)\leq 1.25$<br>$\lambda_c = \dfrac{c}{2}\left(1+\sqrt{1-\dfrac{0.88}{c}}\right)$ |
| | $0>\psi>-1$ | $K_x = F_{long}[7.63-\psi(6.26-10\psi)]$ | | |
| | $\psi\leq -1$ | $K_x = F_{long}\left[5.975(1-\psi)^2\right]$ | | |
| ②   | $1\geq\psi\geq 0$ | $K_y = F_{tran}\dfrac{2\left(1+\frac{1}{\alpha^2}\right)^2}{1+\psi+\frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2}+6.9f_1\right)}$ | | When $\sigma_y \leq 0$, $C_y = 1$;<br>When $\sigma_y > 0$:<br>$C_y = c\left(\dfrac{1}{\lambda}-\dfrac{R+F^2(H-R)}{\lambda^2}\right)$<br>where:<br>$c = (1.25-0.12\psi)\leq 1.25$<br>$R = \lambda\left(1-\dfrac{\lambda}{c}\right)$ for $\lambda < \lambda c$<br>$R = 0.22$ for $\lambda \geq \lambda c$ |
| | | $\alpha \leq 6$ | $f_1 = (1-\psi)(\alpha-1)$ | |
| | | $\alpha > 6$ | $f_1 = 0.6(1-\dfrac{6\psi}{\alpha})(\alpha+\dfrac{14}{\alpha})$<br>but not greater than<br>$14.5-\dfrac{0.35}{\alpha^2}$ | |

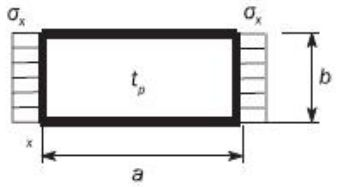
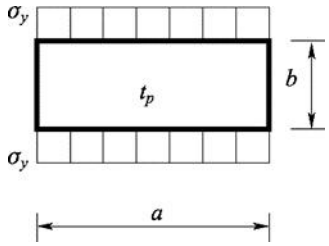
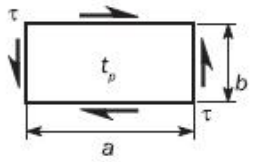
<table>
<tr>
<td></td>
<td>$1-\frac{4\alpha}{3} \le \psi < 0$</td>
<td colspan="2">$K_y = \frac{200F_{tran}\left(1+\beta^2\right)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$</td>
<td rowspan="5">$\lambda_c = 0.5c(1+\sqrt{1-0.88/c})$<br>$F = \left(1-\left(\frac{K}{0.91}-1\right)\Big/\lambda_p^2\right)c_1 \ge 0$<br>$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$<br>$c_1$ as defined in 5.1.1.3.<br>$H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \ge R$<br>$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$</td>
</tr>
<tr>
<td></td>
<td>$\alpha > 6(1-\psi)$</td>
<td>$f_1 = 0.6(\frac{1}{\beta}+14\beta)$<br>but not greater than<br>$14.5-0.35\beta^2$<br>$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$3(1-\psi) \le \alpha \le 6(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-1$<br>$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1.5(1-\psi) \le \alpha < 3(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-(2-\omega\beta)^4-9(\omega\beta-1)(\frac{2}{3}-\beta)$<br>$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1-\psi \le \alpha < 1.5(1-\psi)$</td>
<td>For $\alpha > 1.5$,<br>$f_1 = 2\left(\frac{1}{\beta}-16\left(1-\frac{\omega}{3}\right)^4\right)(\frac{1}{\beta}-1)$<br>$f_2 = 3\beta-2$; $f_3 = 0$<br>For $\alpha \le 1.5$,<br>$f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$</td>
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</table>

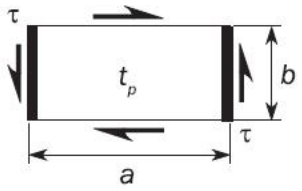
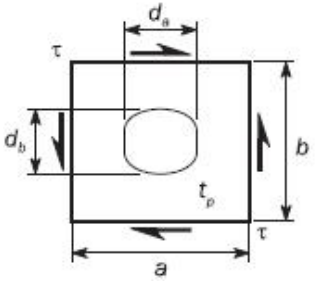
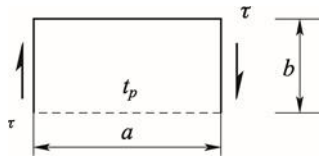
| | | | | |
|---|---|---|---|---|
| | | | $f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$ ; $f_3 = 0$<br>$f_4 = \left[1.5 - Min(1.5;\alpha)\right]^2$ | |
| | | $0.75(1-\psi) \le \alpha < (1-\psi)$ | $f_1 = 0$<br>$f_2 = 1 + 2.31(\beta - 1) - 48\left(\frac{4}{3} - \beta\right) f_4^2$<br>$f_3 = 3f_4(\beta - 1)\left(\frac{f_4}{1.81} - \frac{\alpha - 1}{1.31}\right)$<br>$f_4 = \left[1.5 - \text{Min}(1.5;\alpha)\right]^2$ | |
| | $\psi < 1 - \frac{4\alpha}{3}$ | $K_y = 5.972 F_{tran} \frac{\beta^2}{1 - f_3}$<br>where,<br>$f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$<br>$f_5 = \frac{9}{16}\left[1 + Max(-1;\psi)\right]^2$ | | |
| ③<br>  <br> | $1 \ge \psi \ge 0$ | $K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$ | | For UP-A:<br>$C_x = 1$ for $\lambda \le 0.75$<br>$C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$<br>For UP-B: |
| | $0 > \psi > -1$ | $K_x = 4(0.425 + 1/\alpha^2)(1+\psi)$<br>$-5\psi(1 - 3.42\psi)$ | | |

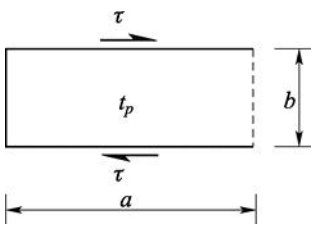
<table>
<tr>
<td>④<br>  </td>
<td>$1 \geq \psi \geq -1$</td>
<td colspan="2">$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$</td>
<td rowspan="3">$C_x = 1$ for $\lambda \leq 0.7$<br>$C_x = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td rowspan="2">⑤<br>  </td>
<td rowspan="2">-</td>
<td>$\alpha \geq 1.64$</td>
<td>$K_x = 1.28$</td>
</tr>
<tr>
<td>$\alpha < 1.64$</td>
<td>$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$</td>
</tr>
<tr>
<td rowspan="2">⑥<br>  </td>
<td>$1 \geq \psi \geq 0$</td>
<td colspan="2">$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$</td>
<td rowspan="2">For UP-A:<br>$C_y = 1$ for $\lambda \leq 0.75$<br>$C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$<br>For UP-B:<br>$C_y = 1$ for $\lambda \leq 0.7$<br>$C_y = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td>$0 > \psi \geq -1$</td>
<td colspan="2">$K_y = 4\left(0.425+\alpha^2\right)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$</td>
</tr>
</table>

| | | | |
|---|---|---|---|
| ⑦<br>  | $1 \geq \psi \geq -1$ | $K_y = \left(0.425 + \alpha^2\right)\frac{3-\psi}{2\alpha^2}$ | |
| ⑧<br>  | -- | $K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$ | |
| ⑨<br>  | — | $K_x = 6.97$ | $C_x = 1$ for $\lambda \leq 0.83$<br>$C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |
| ⑩ | — | $K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$ | $C_y = 1$ for $\lambda \leq 0.83$<br>$C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |

| | | | | |
|---|---|---|---|---|
|  | | | | |
| ⑪<br>  | — | $\alpha \geq 4$ | $K_x = 4$ | $C_x = 1$ for $\lambda \leq 0.83$<br>$C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |
| | | $\alpha < 4$ | $K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$ | |
| ⑫<br>  | - | $K_y$ = $K_y$ determined as per case ② | | For $\alpha < 2$, $C_y = C_{y2}$;<br>For $\alpha \geq 2$,<br>$C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$;<br>where,<br>$C_{y2}$: $C_y$ determined as per case ② |

| | | | | |
|---|---|---|---|---|
| ⑬<br>  | — | $\alpha \geq 4$ | $K_x = 6.97$ | $C_x = 1$ for $\lambda \leq 0.83$<br>$C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |
| | | $\alpha < 4$ | $K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$ | |
| ⑭<br>  | — | $K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^4}\left(\frac{4-1/\alpha}{3}\right)^4$ | | $C_y = 1$ for $\lambda \leq 0.83$<br>$C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |
| ⑮<br>  | — | $K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$ | | $C_\tau = 1$ for $\lambda \leq 0.84$<br>$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$ |
| ⑯ | — | $K_\tau = \sqrt{3}\left[5.34 + \mathrm{Max}\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right]$ | | |

| | | | |
|---|---|---|---|
|  | | | |
| ⑰<br>  | — | $K_\tau = K_{\tau case15} r$<br>$K_{\tau case15}$ : $K_\tau$ according to case ⑮<br>r = opening reduction factor taken as<br>$r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$<br>with<br>$\frac{d_a}{a} \le 0.7$ *and* $\frac{d_b}{b} \le 0.7$ | |
| ⑱<br>  | — | $K_\tau = \sqrt{3}\left(0.6 + \frac{4}{\alpha^2}\right)$ | $C_\tau = 1$ for $\lambda \le 0.84$<br>$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$ |
| ⑲ | — | $K_\tau = 8$ | |

| | | | |
|---|---|---|---|
|  | | | |
| Edge boundary conditions：- - - - - - - - - - - - Plate edge free; ——————Plate edge simply supported; ▬▬▬ Plate edge clamped. | | | |
| Note (1): Cases listed are general cases. Each stress component $(\sigma_x, \sigma_y)$ is to be understood in local coordinates. | | | |

5.2.2.4 Correction factor $F_{long}$

The correction factor $F_{long}$ depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 5.2.2.4. An average value of $F_{long}$ is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 5.2.2.4, the value of c is to be agreed by CCS. In such a case, value of c higher than those mentioned in Table 5.2.2.4 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by CCS.

Correction factor $F_{long}$ Table 5.2.2.4

<table>
<tr><th colspan="3">Structural element types</th><th>$F_{long}$</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="6">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="5">Stiffener fixed at both ends</td><td>Flat bar(1)</td><td rowspan="4">$F_{long} = c + 1 \ for \ \frac{t_w}{t_p} > 1$<br>$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1 \ for \ \frac{t_w}{t_p} \le 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle profile</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover(2)</td><td>(1) Plate on which the U-type profile is fitted, including EPP $b_1$ and EPP $b_2$:<br>● For $b_2 < b_1$: $F_{long}$=1;<br>● For $b_2 \ge b_1$:<br>$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$<br>(2)Other plates of the U-type profile:<br>$F_{long}$=1</td><td>0.2</td></tr>
<tr><td colspan="5">Notes:<br>(1) $t_w$ is the net web thickness, in mm, without the correction defined in [5.4.3.5] of this Section.<br>(2) $b_1$, $b_2$ and $t_w$ are defined in Section 1, Figure 1.2.3.2(2).</td></tr>
</table>

5.2.2.5 Correction factor$F_{tran}$

The correction factor $F_{tran}$ is to be taken as:

(1) For transversely frame EPP of single side skin bulk carrier, between the hopper and top wing tank:

① $F_{tran} = 1.25$ when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels;

② $F_{tran} = 1.33$ when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.

③ $F_{tran} = 1.15$ elsewhere.

(2) For the attached plate of a U-type stiffener fitted on a hatch cover:

$$F_{tran} = \text{Max}\left(3 - 0.08(F_{tran0} - 6)^2, 1.0\right) \le 2.25$$

where:

$$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_2;$$

$$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_1.$$

with $b_1$, $b_2$ and $h_w$ as defined in Figure 1.2.3.2(2) of this Section.

Coefficient $F$ defined in Case 2 of Table 5.2.2.3 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0.91F_{tran}} - 1\right) / \lambda_p^2\right] c_1 \ge 0$$

(3) For other cases, the correction factor $F_{tran}$ is to be taken as 1.0.

5.2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \le 2500$. Otherwise, the requirement for plate limit state given in [5.2.2.1] of this Section is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)^{1.25} - 0.5 \cdot \left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

With the corresponding buckling utilisation factor defined as:

$$\eta_{curved_plate} = \frac{1}{\gamma_c}$$

where:

$\sigma_{ax}$—— Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm$^2$. In case of tensile axial stresses, $\sigma_{ax} = 0$;

$\sigma_{tg}$—— Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm$^2$. In case of tensile tangential stresses, $\sigma_{tg} = 0$;

$C_{ax}, C_{tg}, C_\tau$ —— Buckling reduction factor of the curved plate panel, as defined in Table 5.2.2.6.

The stress multiplier factor, $\gamma_c$, of the curved plate panel need not be taken less than the stress multiplier factor, $\gamma_c$, for the expanded plane panel according to [5.3.1.1] of this Section.

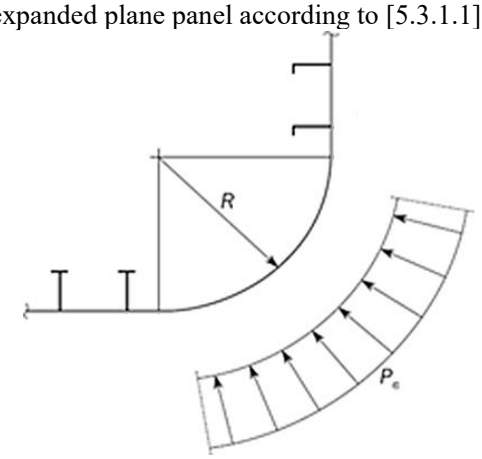
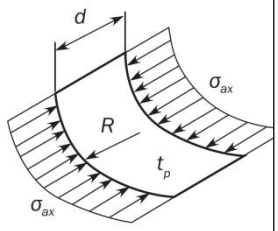
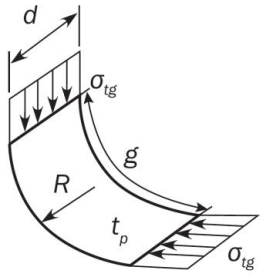
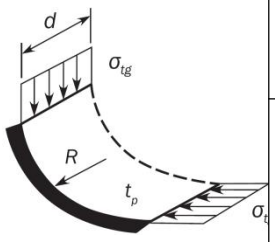
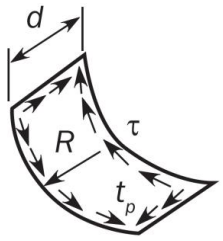



Figure 5.2.2.6 Transverse stiffened bilge plating

Buckling factor and reduction factor for curved plate panel with $R/t_p \le 2500$

Table 5.2.2.6

| Case | Aspect ratio | Buckling factor *K* | Reduction factor *C* |
|---|---|---|---|
| 1<br>  <br> | $\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$ | $K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$ | For general application<br>$C_{ax} = 1$ for $\lambda \le 0.25$<br>$C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \le 1$<br>$C_{ax} = 0.3/\lambda^2$ for $1 < \lambda \le 1.5$<br>$C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$<br>For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6:<br>$C_{ax} = \frac{0.65}{\lambda^2} \le 1.0$ |
| | $\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$ | $K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \ge 0.4\frac{d^2}{Rt_p}$ | |
| 2<br>  <br> | $\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$ | $K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$ | For general application:<br>$C_{tg} = 1$ for $\lambda \le 0.4$<br>$C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$<br>$C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$<br>For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6:<br>$C_{tg} = \frac{0.8}{\lambda^2} \le 1.0$ |
| | $\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$ | $K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$ | |
| 3<br>  <br> | $\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$ | $K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$ | As in load case 2 |
| | $\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$ | $K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R^2}{dt_p}\right)^2$ | |
| 4<br>  <br> | $\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$ | $K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$ | $C_\tau = 1$ for $\lambda \le 0.4$;<br>$C_\tau = 1.274 - 0.686\lambda$,<br>for $0.4 < \lambda \le 1.2$;<br>$C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ |
| | $\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$ | $K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$ | |
| Explanations for boundary conditions<br>- - - - - - - - - - - - Plate edge free;<br>———————— Plate edge simply supported;<br>▬▬▬▬▬▬▬▬ Plate edge clamped. | | | |

5.2.2.7 Applied normal and shear stresses to plate panels

The normal stress, $\sigma_x$ and $\sigma_y$, in N/mm$^2$, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

(1) For FE analysis, the reference stresses as defined in Section 4, [4.2.4];

(2) For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to the Relevant UR-S, at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in (1) and (2) of Section 3, [3.1.2.1] respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in (1) of Section 3, [3.1.2.1].

(3) For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1 - \nu^2}$$
$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1 - \nu^2}$$

where:

$\sigma_{xb}, \sigma_{yb}$ —— Stress, in N/mm$^2$, from grillage beam analysis respectively along $x$ and $y$ axis of the plate attached to the PSN web.

The shear stress, $\tau$, in N/mm$^2$, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

① For FE analysis, the reference shear stresses as defined in Section 4, [4.2.4];

② For prescriptive assessment of the plate panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at load calculation points of the considered elementary plate panel, as defined in (1) of Section 3, [3.1.2.1];

③ For prescriptive assessment of the overall elastic stiffened panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at the following load calculation point:

(a) At the middle of the full span, $l$, of the considered stiffener;

(b) At the intersection point between the stiffener and its attached plating.

(4) For grillage beam analysis, $\tau = 0$ in the plate attached to the PSM web.

### 5.2.3 Stiffeners

5.2.3.1 Buckling modes

The following buckling modes are to be checked:

(1) Stiffener induced failure (*SI*);

(2) Associated plate induced failure (*PI*).

5.2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bat stiffener, in mm, is to be used in [5.2.1] and [5.2.3.4] for the calculation of the net sectional area, $A_s$, the net section modulus, $Z$, and the moment of inertia, $I$, of the stiffener and is taken as:

$$t_{w_red} = t_w \left( 1 - \frac{2\pi^2}{3} \left( \frac{h_w}{s} \right)^2 \left( 1 - \frac{b_{eff1}}{s} \right) \right)$$

5.2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained from the following formulae:

$$h_w = h_w^{'} - \frac{h_w^{'}}{9.2} + 2$$

$$b_f = \alpha \left( t_w^{'} + \frac{h_w^{'}}{6.7} - 2 \right)$$

$$t_f = \frac{h_w^{'}}{9.2} - 2$$

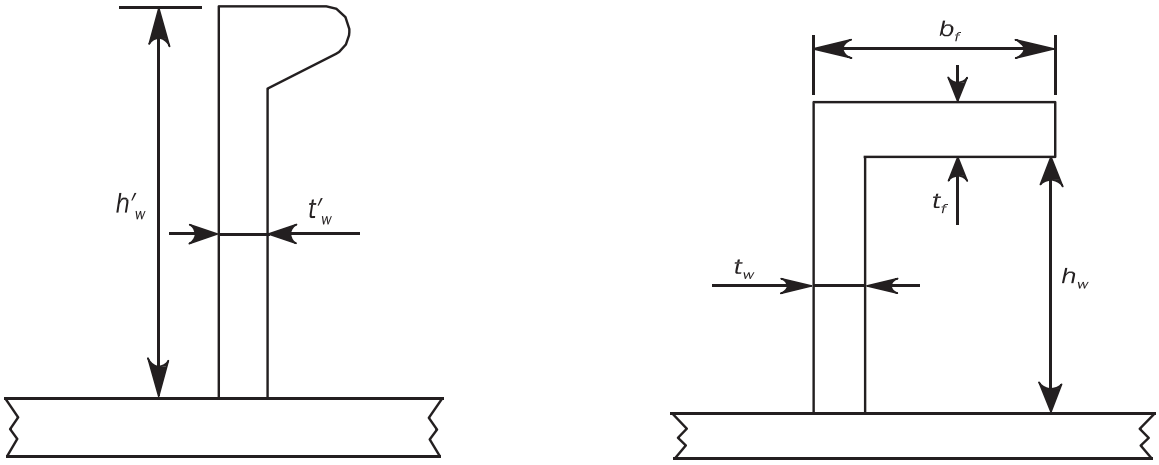
$$t_w = t_w^{'}$$

where: $h_w^{'}, t_w^{'}$——Net height and thickness of a bulb section, in mm, as shown in Figure 5.2.3.3;

$\alpha$ ——Coefficient equal to:

$$\alpha = 1.1 + \frac{\left(120 - h_w^{'}\right)^2}{3000} \quad \text{for} \quad h_w^{'} \leq 120$$

$$\alpha = 1.0 \qquad \text{for} \quad h_w^{'} > 120.$$




**Bulb flat** **Equivalent angle bar**

Figure 5.2.3.3 Idealisation of bulb stiffener

5.2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$ while initially setting γ = 1, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{stiffener} = \frac{1}{\gamma_c}$$

where:

$\sigma_a$ —— Effective axial stress, in N/mm$^2$, at mid span of the stiffener, acting on the stiffener with its attached plating

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1} t_p + A_s} \quad .$$

$\sigma_x$ —— Nominal axial stress, in N/mm$^2$, acting on the stiffener with its attached plating:

(1) For FE analysis, $\sigma_x$ is the FE corrected stress as defined in [5.2.3.6] in the attached plating in the direction of the stiffener axis;

(2) For prescriptive assessment, $\sigma_x$ is the axial stress, in N/mm$^2$, calculated according to Section 3, [3.2.2.1] at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1];

(3) For grillage beam analysis, $\sigma_x$ is the stress acting along the *x*-axis of the attached buckling panel.

$R_{eH}$ —— Specified minimum yield stress of the material, in N/mm$^2$:

(1) $R_{eH} = R_{eH_S}$ for stiffener induced failure *(SI)*;

(2) $R_{eH} = R_{eH_P}$ for plate induced failure *(PI)*.

$\sigma_b$ —— Bending stress in the stiffeners, in N/mm$^2$:

$\sigma_b = \frac{M_0+M_1+M_2}{1000Z}$.

$Z$ —— Net section modulus of stiffener, including effective width of attached plating according to [5.2.3.5], to be taken as:

(1) The section modulus calculated at the top of stiffener flange for stiffener induced failure *(SI)*;

(2) The section modulus calculated at the bottom of attached plating for plate induced failure *(PI)*.

$M_2$ —— Bending moment, in N·mm, due to eccentricity of sniped stiffeners, to be taken as:

(1) $M_2 = 0$ for continuous stiffeners;

(2) $M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.

$C_{snip}$ —— Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as:

(1) $C_{snip} = -1.2$ for stiffener induced failure *(SI)*;

(2) $C_{snip} = 1.2$ for plate induced failure (*PI*).

$\sigma_w$ —— Stress due to torsion, in N/mm$^2$, as defined in [5.4.4.4].

$M_1$ —— Bending moment, in N·mm, due to the lateral load, *P,* taken as follows:

(1) $M_1 = C_i \frac{|P| s l^2}{24\times10^3}$ for continuous stiffener;

(2) $M_1 = C_i \frac{|P| s l^2}{8\times10^3}$ for sniped stiffener at both ends;

(3) $M_1 = C_i \frac{|P| s l^2}{14.2\times10^3}$ for stiffener sniped at one end and continuous at the other end.

$P$ —— Lateral load, in kN/m$^2$:

(1) For FE analysis， $P$ is the average pressure as defined in Section 4, [4.2.5.2] in the attached plating;

(2) For prescriptive assessment, $P$ is the static pressure calculated at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1].

$C_i$ —— Pressure coefficient:

(1) $C_i = C_{SI}$ for stiffener induced failure (*SI);*

(2) $C_i = C_{PI}$ for plate induced failure (*PI).*

$C_{PI}$ —— Plate induced failure pressure coefficient:

(1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

$C_{SI}$ —— Stiffener induced failure pressure coefficient:

(1) $C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

$M_0$ —— Bending moment, in Nmm, due to the lateral deformation *w* of stiffener:

$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB}-\gamma} w_0$ with precondition $\gamma_{GEB} - \gamma > 0$.

$\gamma_{GEB}$ —— Stress multiplier factor of global elastic buckling capacity as defined in [5.2.1].

$F_E$ —— Ideal elastic buckling force of the stiffener, in N:

$F_E = \left(\frac{\pi}{l}\right)^2 EI \times 10^4$.

$I$ —— Moment of inertia, in cm$^4$, of the stiffener including effective width of attached plating. *I* is to comply with the following requirement:

$I \geq \frac{s t_p^3}{12\times10^4}$.

$t_p$ (1) —— Net thickness of plate, in mm, to be taken as:

(2) For prescriptive requirements: the mean thickness of the two attached plating panels;

(3) For FE analysis, the thickness of the considered EPP on one side of the stiffener.

$C_{sl}$ —— Deformation reduction factor to account for global slenderness, to be taken as:

(1) $C_{sl} = 1 - \frac{1}{12}\lambda_G^4$ for $\lambda_G \leq 1.56$;

(2) $C_{sl} = 3/\lambda_G^4$ for $\lambda_G > 1.56$.

$\lambda_G$ —— The reference degree of global slenderness of the stiffened panel, to be taken as:

$$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}}$$

where: $\gamma_{ReH} = \frac{\text{Min}\,(R_{eH_P},\ R_{eH_S})}{\sqrt{\sigma_{x,av}^2+\sigma_y^2-\sigma_{x,av}\sigma_y+3\tau^2}}$ .

$\sigma_{x,av}$ —— Average stress for both plate and stiffener as defined in [5.2.1.2].

$\sigma_y$ —— Applied transverse stress to the plate panel as defined in [5.2.1.1].

$\tau$ —— Applied shear stress to the plate panel as defined in [5.2.1.1].

$w_0$ —— Assumed imperfection, in mm, to be taken as:

$$w_0 = l/1000;$$

$\sigma_w$ —— Stress due to torsional deformation, in N/mm$^2$, to be taken as:

(1) For stiffener induce failure (*SI)*

① For $\sigma_a > 0$:

$$\sigma_w = Ey_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1-\frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right) \text{ with precondition } \sigma_{ET} - \gamma\sigma_a > 0$$

② For $\sigma_a \le 0$:

$$\sigma_w = 0$$

(2) For plate induced failure (*PI)*

$$\sigma_w = 0$$

$y_w$ —— Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

(1) $y_w = \frac{t_w}{2}$ for flat bar;

(2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;

(3) $y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f\left(b_f^2 - 2b_f d_f\right)}{2A_s}$ for L2 profile;

(4) $y_w = \frac{b_f}{2}$ for T profile.

$\Phi_0$ —— Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor}h_w} \times 10^{-4}.$$

$\sigma_{ET}$ —— Reference stress for torsional buckling, in N/mm$^2$, to be taken as:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 I_\omega \times 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \times 10^{-4}\right].$$

$I_p$ —— Net polar moment of inertia of the stiffener defined in Table 5.4.4.4, in cm$^4$, about point *C* as shown in Section 1 Figure 1.2.3.2, as defined in Table 5.2.3.4.

$I_T$ —— Net St. Venant's moment of inertia of the stiffener, in cm$^4$, as defined in Table 5.2.3.4.

$I_\omega$ —— Net sectional moment of inertia of the stiffener, in cm$^6$, about point *C* as shown in Section 1, Figure 1.2.3.2(1), as shown in Table 5.2.3.4.

$l_{tor}$ —— Stiffener span, in mm, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, $l_{tor}$ is to be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

$m_{tor}$ —— Number of half waves, taken as a positive integer so as to give smallest reference stress for torsional buckling.

$\varepsilon$ —— Degree of fixation, to be taken as:

$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1}$ for bulb, angle, L2 and T profiles;

$\varepsilon = \left(\frac{t_p^3}{3b}\right)$ for flat bars.

$A_w$ —— Net web area, in mm$^2$;

$A_f$ —— Net flange area, in mm$^2$.

Moment of inertia Table 5.2.3.4

| Cross section characteristics | Flat bars | Bulb, angle, L2 and T profiles |
|---|---|---|
| $I_p$ | $\frac{h_w^3 t_w}{3\times 10^4}$ | $\left(\frac{A_w(e_f-0.5t_f)^2}{3}+A_f e_f^2\right)\times 10^{-4}$ |
| $I_T$ | $\frac{h_w t_w^3}{3\times 10^4}\left(1-0.63\frac{t_w}{h_w}\right)$ | $\frac{(e_f-0.5t_f)t_w^3}{3\times 10^4}\left(1-0.63\frac{t_w}{e_f-0.5t_f}\right)+\frac{b_f t_f^3}{3\times 10^4}\left(1-0.63\frac{t_f}{b_f}\right)$ |
| $I_\omega$ | $\frac{h_w^3 t_w^3}{36\times 10^6}$ | For bulb, angle and L2 profiles: $\frac{A_f^3+A_w^3}{36\times 10^6}+\frac{e_f^2}{10^6}\left(\frac{A_f b_f^2+A_w t_w^2}{3}-\frac{(A_f b_f+A_w t_w)^2}{4(A_f+A_w)}\right)$ For T profile: $\frac{b_f^3 t_f e_f^3}{12\times 10^6}$ |
| Notes: (1) $t_w$ is the net web thickness, in mm. $t_{w_red}$ as defined in [5.2.3.2] is not to be used in this Table; (2) $d_f$ is to be taken as 0 for bulb and angle profiles. | | |

5.2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, $b_{eff}$ in mm, is to be taken as:

(1) For $\sigma_x > 0$:

① For FE analysis,

$$b_{eff} = Min\,(C_x b, \chi_s s)$$

② For prescriptive assessment,

$$b_{eff} = Min\left(\frac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s\right)$$

(2) For $\sigma_x \le 0$:

$$b_{eff} = \chi_s s$$

where: $\chi_s$ —— Effective width coefficient to be taken as:

① $\chi_s = \frac{1.12}{1+\frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}} \le 1.0$ for $\frac{\ell_{eff}}{s} \ge 1$

② $\chi_s = 0.407\frac{\ell_{eff}}{s}$ for $\frac{\ell_{eff}}{s} < 1.$

$\ell_{eff}$—— Effective length of the stiffener, in mm, taken as:

(1) $\ell_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $\ell_{eff} = 0.75l$ for stiffener simply supported at one end and fixed a the other.

(3) $\ell_{eff} = l$ for stiffener simply supported at both ends.

5.2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses $\sigma_x$ and $\sigma_y$ obtained by FE analysis according to Section 4, [4.2.4] are both compressive, $\sigma_x$ is to be corrected according to the following formulae:

(1) If $\sigma_x < \nu\sigma_y$

$$\sigma_{xcor} = 0$$

(2) If $\sigma_x \geq \nu\sigma_y$

$$\sigma_{xcor} = \sigma_x - \nu\sigma_y$$

### 5.2.4 Primary Supporting Members

5.2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 5.2.4.1.

The interaction formulae of [5.2.2.1] are to be used with:

$$\sigma_x = \sigma_{av}$$

$$\sigma_y = 0$$

$$\tau = \tau_{av}$$

where: $\sigma_{av}$ —— Weighted average compressive stress, in N/mm$^2$, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

For the application of Table 5.2.4.1, the weighted average shear stress is to be taken as:

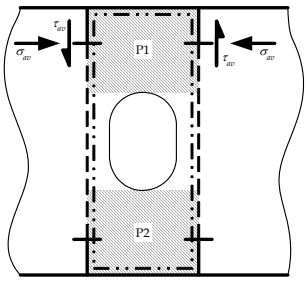
(1) Opening modelled in primary supporting members:

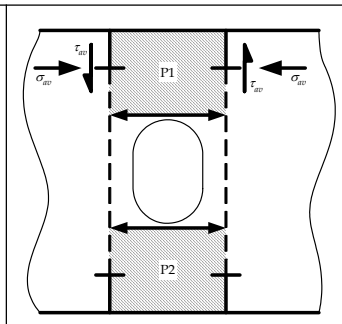
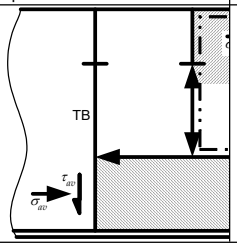
$\tau_{av}$ —— Weighted average compressive stress, in N/mm$^2$, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

(2) Opening not modelled in primary supporting members:

$\tau_{av}$ —— Weighted average shear stress, in N/mm$^2$, given in Table 5.2.4.1.

Buckling reduction factors of web plate in way of openings Table 5.2.4.1

| **Configuration** (1) | | $C_x, C_y$ | $C_\tau$ | |
|---|---|---|---|---|
| | | | **Opening modelled in PSM** | **Opening not modelled in PSM** |
| (a) Without edge reinforcements (2) |  | Separate reduction factors are to be applied to areas *P1* and *P2* using case ③ or case ⑥ in Table 5.2.2.3, with edge stress ratio:<br>ψ＝1.0 | Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ in Table 5.2.2.3. | When case ⑰ of Table 5.2.2.3 is applicable: A common reduction factor is to be applied to areas *P1* and *P2* using case ⑰ with:<br>$\tau_{av} = \tau_{av}\,(web)$;<br>When case ⑰ of Table 5.2.2.3 is not applicable: Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ with:<br>$\tau_{av} = \tau_{av}\,(web)h/(h - h_0)$ |

| Configuration (1) | | $C_x, C_y$ | $C_\tau$ | |
|---|---|---|---|---|
| | | | Opening modelled in PSM | Opening not modelled in PSM |
| (b) With edge reinforcement |  | Separate reduction factors are to be applied for areas *P1* and *P2* using $C_x$ for case ① or $C_y$ for case ② in Table 5.2.2.3 with stress ratio: ψ＝1.0. | Separate reduction factors are to be applied for areas *P1* and *P2* using case ⑮ in Table 5.2.2.3. | Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑮ in Table 5.2.2.3 with: $\tau_{av} = \tau_{av}\,(web)h/\,(h - h_0)$ |
| (c) Example of hole in web | |  | Panels *P1* and *P2* are to be evaluated in accordance with (a). Panel *P3* is to be evaluated in accordance with (b). | |

where:
$h$ —— Height, in m, of the web of the primary supporting member in way of the opening;
$h_0$—— Height, in m, of the opening measured in the depth of the web;
$\tau_{av}\,(web)$ —— Weighted average shear stress, in N/mm$^2$, over the web height of the primary supporting member.

Note (1) Web panels to be considered for buckling in way of openings are shown shaded and numbered *P1*, *P2*, etc.
Note (2) For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.

5.2.4.2 Reduction factors of web plate in way of openings
The reduction factors, $C_x$ or $C_y$ in combnaiton with $C_\tau$ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 5.2.4.1.
5.2.4.3 The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Figure 5.2.4.3.
The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

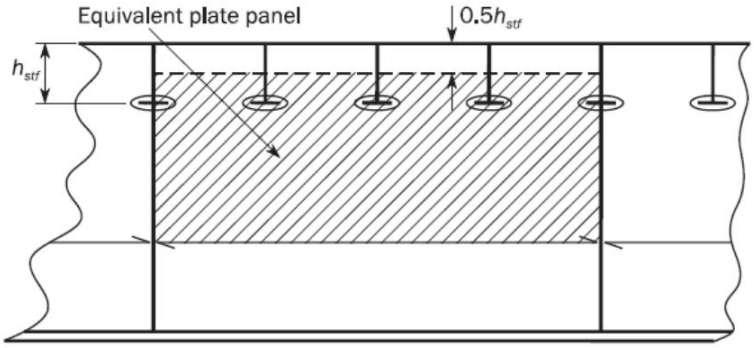



Figure 5.2.4.3 PMS web plate idealisation

### 5.2.5 Stiffened Panels with U-type Stiffeners

5.2.5.1 Local plate buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP $b_1, b_2, b_f$ and $h_w$ (see Section 1, Figure 1.2.3.2(2)) separately as follows:

(1) The attached plate panels EPP $b_1, b_2$ are to be assessed using SP-A model, where in the calculation of buckling factors $K_x$ as defined in Case ① of Table 5.2.2.3, the correction factor $F_{long}$ for U-type stiffeners as defined in Table 5.2.2.4 is to be used; and in the calculation of $K_y$ as defined in Case ② of Table, the $F_{tran}$ for U-type stiffeners as defined in [5.2.2.5] is to be used.

(2) The face plate and web plate panels EPP $b_f$ and $h_w$ are to be assessed using UP-B model with $F_{long} = 1$ and $F_{tran} = 1$.

5.2.5.2 Overall stiffened panel buckling and stiffener buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress $\sigma_w$ = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

(1) The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to $t_w$ and height equal to the distance between the attached plate and the face plate of the stiffener.

(2) Effective width of the attached plating $b_{eff}$, taken as the sum of the $b_{eff}$ calculated for EPP, $b_1$ and $b_2$ respectively according to SP-A model.

(3) Effective width of the attached plating of a stiffener without shear lag effect, $b_{eff1}$, taken as the sum of the $b_{eff1}$ calculated for the EPP, $b_1$ and $b_2$ respectively.

## 5.3 Buckling capacity of column structures

### 5.3.1 Column Buckling of Corrugations

5.3.1.1 Buckling utilisation factor

The column buckling utilisation factor, $\eta$, for axially compressed corrugations is to be taken as:

$$\eta_{column} = \frac{\sigma_{av}}{\sigma_{cr}}$$

where: $\sigma_{av}$ —— Average axial compressive stress in the member, in N/mm$^2$;

$\sigma_{cr}$ —— Minimum critical buckling stress, in N/mm$^2$, taken as:

① $\sigma_{cr} = \sigma_E$ for $\sigma_E \leq 0.5R_{eH_S}$

② $\sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S}$ for $\sigma_E > 0.5R_{eH_S}$ ;

$\sigma_E$ —— Elastic column compressive buckling stress, in N/mm$^2$, according to [5.3.1.2];

$R_{eH_S}$ —— Specified minimum yield stress of the considered member, in N/mm$^2$. For built-up members, the lowest specified minimum yield stress is to be used.

5.3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, $\sigma_E$, in N/mm$^2$ of members subject to axial compression is to be taken as:

$$\sigma_E = \pi^2 E f_{end} \frac{I}{A l_{pill}^2} \times 10^{-4}$$

where: $I$ —— Net moment of inertia about the weakest axis of the cross section, in cm$^4$;

$A$ —— Net cross-sectional area of the member, in cm$^2$;

$l_{pill}$ —— Unsupported length of the member, in m;

$f_{end}$ —— End constraint factor, corresponding to simply supported ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation, taken as:

- $f_{end} = 1.0$ where both ends are simply supported;
- $f_{end} = 2.0$ where one end is simply supported and the other end is fixed;
- $f_{end} = 4.0$ where both ends are fixed.

# SECTION 6 STRESS BASED REFERENCE STRESSES

**Symbols**

$a$ —— Length, in mm, of the longer side of the plate panel as defined in Section 5;

b —— Length, in mm, of the shorter side of the plate panel as defined in Section 5;

$A_i$ —— Area, in $mm^2$, of the i-th plate element of the buckling panel;

n —— Number of plate elements in the buckling panel;

$\sigma_{xi}$ —— Actual stress, in $N/mm^2$, at the centroid of the *i*-th plate element in *x* direction, applied along the shorter edge of the buckling panel;

$\sigma_{yi}$ —— Actual stress, in $N/mm^2$, at the centroid of the *i*-th plate element in *y* direction, applied along the longer edge of the buckling panel;

$\psi$ —— Edge stress ratio as defined in Section 5;

$\tau_i$ —— Actual membrane shear stress, in $N/mm^2$, at the centroid of the *i*-th plate element of the buckling panel.

## 6.1 Stress Based Method

### 6.1.1 Introduction

6.1.1.1 This Section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

6.1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Section 4, [4.2.3.1].

### 6.1.2 Stress Application

6.1.2.1 Regular panel

The reference stresses are to be taken as defined in [6.2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge *a* of a regular panel; and
- This element center is located at a distance in the panel local *x* direction not less than *a*/4 to at least one of the element centers in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [6.2.2] for an irregular panel.

6.1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [6.2.2].

## 6.2 Reference Stresses

### 6.2.1 Regular Panel

6.2.1.1 Longitudinal stress

The longitudinal stress $\sigma_x$ applied on the shorter edge of the buckling panel is to be calculated as follows:

For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as second order polynomial curve as:

$$\sigma_x = Cx^2 + Dx + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error $\Pi$ considering the area of each element as a weighting factor:

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{xi} - (Cx_i^2 + Dx_i + E)\right]^2$$

The unknown coefficients *C*, *D* and *E* is yield zero first derivatives, $\partial\Pi$ with respect to *C, D* and *E,* respectively.

$$\begin{cases} \dfrac{\partial \Pi}{\partial C} = 2\sum_{i=1}^{n} A_i x_i^2 \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial D} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial E} = 2\sum_{i=1}^{n} A_i \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \end{cases}$$

The unknown coefficients *C, D* and *E* can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, , $\sigma_{x3}$ is to be ignored. Otherwise, $\sigma_{x3}$ is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x_{min}}^{x_{max}} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where: $x_{min} = -\frac{b}{2} - \frac{D}{2C}$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = Max\left(\sigma_{x1}, \sigma_{x2}, \sigma_{x3}\right) \ ;$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress $\sigma_x$ applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

The edge stress ratio $\psi_x$ for the stress $\sigma_x$ is equal to 1.0.

6.2.1.2 Transverse stress

The transverse stress $\sigma_y$ applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

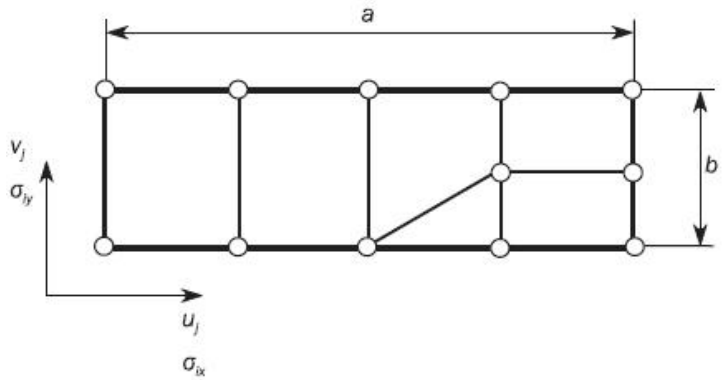



Figure 6.2.1.2 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error $\Pi$ considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right]^2$$

The unknown coefficients *A* and *B* are to yield zero first partial derivatives, $\partial\Pi$ with respect to *A* and *B*, respectively.

$$\frac{\partial\Pi}{\partial A} = 2\sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

$$\frac{\partial\Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

The unknown coefficients *A* and *B* are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

$$B = \frac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i\sigma_{yi}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

The transverse stress is to be taken as:

$$\sigma_y = max\,(A, A + Ba)$$

The edge stress ratio is to be taken as:

$$\psi_y = \frac{min\,(A, A + Ba)}{max\,(A, A + Ba)} \text{ for } \sigma_y > 0$$

$$\psi_y = 1 \text{ for } \sigma_y \leq 0.$$

6.2.1.3 Shear stress

The shear stress $\tau$ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{i=1}^{n} A_i\tau_i}{\sum_{i=1}^{n} A_i}$$

### 6.2.2 Irregular Panel and Curved Panel

6.2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i\sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^{n} A_i\sigma_{yi}}{\sum_{i=1}^{n} A_i}$$

$$\tau = \frac{\sum_{i=1}^{n} A_i\tau_i}{\sum_{i=1}^{n} A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1;$$

$$\psi_y = 1.$$

# CHAPTER 3 EQUIPMENT AND OUTFITS

## Section 1 RUDDERS

### 3.1.1 General requirements

3.1.1.1 Basic assumptions

(1) This Section applies to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force. Rudders not conforming to the profile types included in this Section will be subject to special consideration.

(2) This section applies to rudders made of steel. Rudders made of material different from steel will be subject to special consideration.

3.1.1.2 Design considerations

(1) Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

(2) Suitable arrangements are to be provided to prevent the rudder from lifting.

(3) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the waterline at scantling draught (without trim), two separate watertight seals/stuffing boxes are to be provided.

3.1.1.3 Materials

(1) Welded parts of rudders are to be made of materials complying with relevant requirements for hull structural steel in CCS Rules for Materials and Welding.

(2) Material factor $k$ for normal and high tensile steel plating may be taken into account when specified in each individual rule requirement. The material factor $k$ is to be taken as defined in Section 3, Chapter 1 of this PART, unless otherwise specified.

(3) Steel grade of plating materials for rudders and rudder horns are to be in accordance with Section 3, Chapter 1 of this PART.

(4) Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with CCS Rules for Materials and Welding.

(5) For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm$^2$. The requirements of this Section are based on a material's yield stress of 235 N/mm$^2$. If material is used having a yield stress differing from 235 N/mm$^2$ the material factor $K$ is to be determined as follows:

$$K=\left(\frac{235}{R_{eH}}\right)^{e}$$

where: $e$ = 0.75 for $R_{eH} > 235$ N/mm$^2$;

$e$ = 1.00 for $R_{eH} \leq 235$ N/mm$^2$;

$R_{eH}$ —specified minimum yield stress (N/mm$^2$) of material used, and is not to be taken greater than $0.7R_m$ or 450 N/mm$^2$, whichever is the smaller value;

$R_m$ — tensile strength (N/mm$^2$) of material used.

3.1.1.4 Welding and design details

(1) Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of slots is to be minimum 75 mm with breadth of 2$t$, where t is the rudder plate thickness, in mm. The distance between ends of slots is not to be more than 125 mm. The fillet leg length is to comply with calculation requirements in 1.4.4, Section 1, Chapter 1 of this PART, and welding is to be based on a weld factor of 0.44. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds are to be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15°.

(2) In way of the rudder horn recess of semi-spade rudders, the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

(3) Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as

full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the bevelled edge, see Figure 3.1.1.4(3). The bevel angle is to be at least 15° for one sided welding.

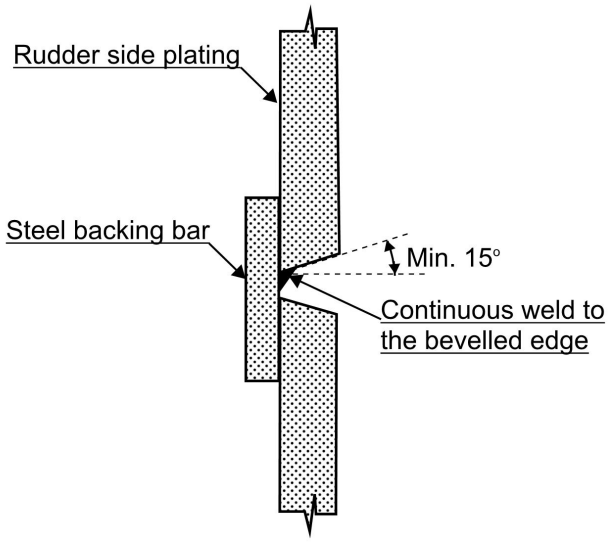



**Figure 3.1.1.4(3) Use of steel backing bar in way of full penetration welding of rudder side plating**

(4) Requirements for welding and design details of rudder trunks are described in 3.1.9.2 of this Section.
(5) Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in 3.1.6.1(4) of this Section.
(6) Requirements for welding and design details of rudder horns are described in 3.1.9.1(3).

3.1.1.5 Equivalence

(1) Alternatives to requirements given in this Section may be accepted, provided they are deemed to be equivalent.
(2) Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.
(3) Where deemed necessary, lab tests, or full scale tests may be requested to validate the alternative design approach.

### 3.1.2 Rudder force and rudder torque

3.1.2.1 Rudder blades without cut-outs

(1) The rudder force $C_R$ upon which the rudder scantlings are to be based is to be determined from the following formula:

$$C_R = 132 K_1 K_2 K_3 A V^2 \quad \text{N}$$

where: $C_R$ — rudder force, in N;
$A$ — area of rudder blade, in $m^2$;
$V$ — maximum service speed (knots). When the speed is less than 10 knots, $V$ is to be replaced by the following:
$V_{min} = (V + 20) / 3$
For the astern condition the maximum astern speed $V_{astern}$ (the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught) is to be used, however, in no case less than:
$V_{astern} = 0.5\ V$;
$K_1$ — factor depending on the aspect ratio $\lambda$ of the rudder area;
$K_1 = (\lambda + 2)/3$, with $\lambda$ not to be taken greater than 2;
$\lambda = b^2/A_t$;
$b$ — mean height of the rudder area, in m. Mean breadth and mean height of rudder are calculated according to the coordinate system in Figure 3.1.2.1;
$A_t$ — sum of rudder blade area $A$ and area of rudder post or rudder horn, if any, within the height $b$, in $m^2$;

$K_2$ — coefficient depending on the type of the rudder and the rudder profile according to Table 3.1.2.1; data may be provided by tests with approval;

$K_3$ = 0.8 for rudders outside the propeller jet;
= 1.15 for rudders behind a fixed propeller nozzle;
= 1.0 otherwise.

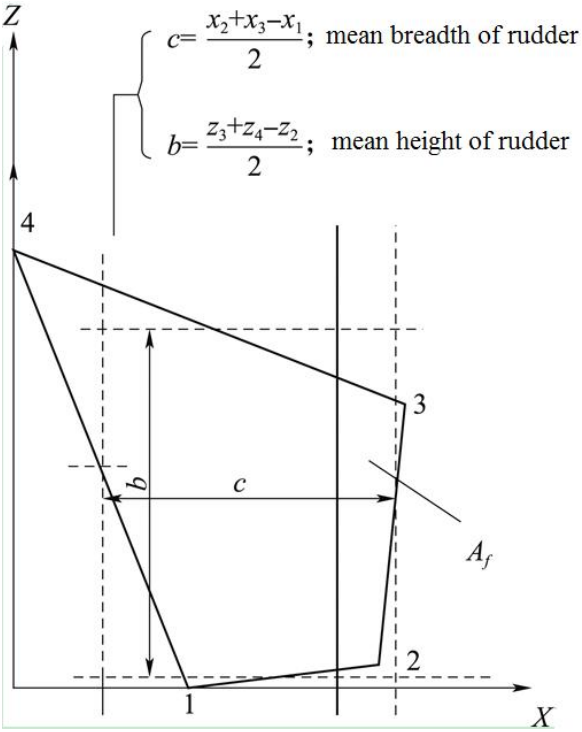
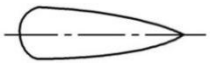
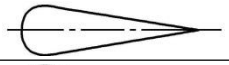
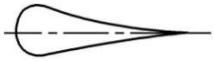
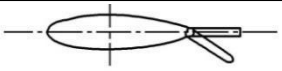
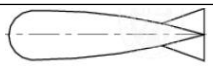



**Figure 3.1.2.1**

**Factor $K_2$** **Table 3.1.2.1**

| Profile Type | | $K_2$ | |
|---|---|---|---|
| | | Ahead condition | Astern condition |
| NACA-00 series Göttingen |  | 1.1 | 0.80 |
| Flat side |  | 1.1 | 0.90 |
| Hollow |  | 1.35 | 0.90 |
| High lift rudders |  | 1.7 | 1.30 |
| Fish tail |  | 1.4 | 0.8 |
| Single plate |  | 1.0 | 1.0 |
| Mixed profiles (e.g. HSVA) | | 1.21 | 0.9 |

(2) The rudder torque $Q_R$ is to be calculated for both the ahead and astern condition as follows:

$$Q_R = C_R r \quad \text{Nm}$$

where: $r = c(\alpha - k)$, in m;

$c$ — mean breadth of rudder area, in m, see Figure 3.1.2.1;

$\alpha$ — coefficient, taken as 0.33 for ahead condition and 0.66 for astern condition; special consideration may be given for high lift rudders, and taken as 0.40 for ahead condition and 0.66 for astern condition if no test data may be provided;

$$k = \frac{A_f}{A};$$

$A_f$ — portion of the rudder blade area situated ahead of the centre line of the rudder stock, in m$^2$;

$r_{\min} = 0.1c$, in m, for ahead condition.

3.1.2.2 Rudder blades with cut-outs (semi-spade rudders)

The total rudder force $C_R$ is to be calculated according to 3.1.2.1(1) of this Section. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas $A_1$ and $A_2$, so that $A = A_1 + A_2$ (see Figure 3.1.2.2).

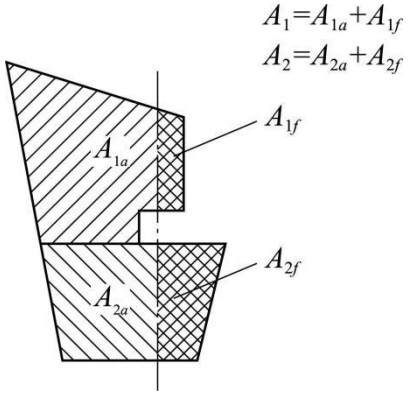



**Figure 3.1.2.2 Areas $A_1$ and $A_2$**

The levers $r_1$ and $r_2$ are to be determined as follows:

$$r_1 = c_1(\alpha - k_1), \text{ m};$$

$$r_2 = c_2(\alpha - k_2), \text{ m};$$

where: $c_1$, $c_2$ — mean breadth of partial areas $A_1$, $A_2$ determined, where applicable, in accordance with Figure 3.1.2.1;

$$k_1 = \frac{A_{1f}}{A_1};$$

$$k_2 = \frac{A_{2f}}{A_2};$$

$A_{1a}$ —portion of $A_1$ situated aft of the centre line of the rudder stock, in m$^2$;

$A_{1f}$ — portion of $A_1$ situated ahead of the centre line of the rudder stock, in m$^2$;

$A_{2a}$ —portion of $A_2$ situated aft of the centre line of the rudder stock, in m$^2$;

$A_{2f}$ — portion of $A_2$ situated ahead of the centre line of the rudder stock, in m$^2$;

$\alpha$ = 0.33 for ahead condition;

$\alpha$ = 0.66 for astern condition;

For parts of a rudder behind a fixed structure such as the rudder horn:

$\alpha$ = 0.25 for ahead condition;

$\alpha$ = 0.55 for astern condition;

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \quad \text{N}$$

$$C_{R2} = C_R \frac{A_2}{A} \quad \text{N}$$

The resulting torque of each part may be taken as:

$$Q_{R1} = C_{R1} r_1 \quad \text{Nm}$$
$$Q_{R2} = C_{R2} r_2 \quad \text{Nm}$$

The total rudder torque is to be calculated for both the ahead and astern condition as follows:

$$Q_R = Q_{R1} + Q_{R2} \quad \text{Nm}$$

For ahead condition $Q_R$ is not to be taken less than:

$$Q_{R\min} = 0.1 C_R \frac{A_1 c_1 + A_2 c_2}{A} \quad \text{Nm}$$

**3.1.3 Rudder strength calculation**

3.1.3.1 The rudder force and resulting rudder torque as given in 3.1.2 of this Section causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces. The rudder body is to be stiffened by horizontal and vertical webs enabling it to act as a bending girder.

3.1.3.2 The bending moments, shear forces and torques as well as the reaction forces are to be determined by a direct calculation or by an approximate simplified method as approved. For rudders supported by sole pieces or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body. Guidelines for calculation of bending moment and shear force distribution are given in Appendix 1 to this Chapter.

**3.1.4 Rudder stock scantlings**

3.1.4.1 The rudder stock diameter required for the transmission of the rudder torque is to be dimensioned such that the torsional stress $\tau_t$ is not exceeding the following value:

$$\tau_t = 68 / K \quad \text{N/mm}^2$$

The rudder stock diameter for the transmission of the rudder torque $d_t$ is therefore not to be less than:

$$d_t = 4.2 \sqrt[3]{Q_R K} \quad \text{mm}$$

where: $Q_R$ — total rudder torque [N·m] as calculated in 3.1.2.1(2) and 3.1.2.2 of this Section;

$K$ — material factor for the rudder stock as given in 3.1.1.3(5) of this Section.

3.1.4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed $118 / K$ N/mm$^2$.

$K$ — material factor for the rudder stock as given in 3.1.1.3(5).

The equivalent stress $\sigma_c$ is to be determined by the formula:

$$\sigma_c = \sqrt{\sigma_b^{\,2} + 3\tau_t^{\,2}} \quad \text{N/mm}^2$$

where: bending stress: $\sigma_b = \frac{10.2M}{d_c^3} \times 10^3$ N/mm$^2$;

torsional stress: $\tau_t = \frac{5.1 Q_R}{d_c^3} \times 10^3$ N/mm$^2$.

The rudder stock diameter $d_c$ is therefore not to be less than:

$$d_c = d_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M}{Q_R}\right)^2} \quad \text{mm} \qquad \text{mm}$$

where: $M$ — bending moment, in N·m, at the station of the rudder stock considered.

For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

3.1.4.3 Before significant reductions in rudder stock diameter due to the application of steels with specified minimum yield stresses exceeding 235 N/mm$^2$ are granted, the evaluation of the rudder stock deformations may be required. Large deformations of the rudder stock are to be avoided in order to avoid excessive edge pressures in way of bearings.

**3.1.5 Rudder blade**

3.1.5.1 Permissible stresses

The section modulus and the web area of a horizontal section of the rudder blade are to be such that the following stresses will not be exceeded:

(1) In general, except in way of rudder recess sections where (2) applies

① bending stress $\sigma_b$ $110/k$ N/mm$^2$

② shear stress $\tau$ $50/k$ N/mm$^2$

③ equivalent stress $\sigma_e=\sqrt{\sigma_b^2+3\tau^2}$ $120/k$ N/mm$^2$

$K$ — material factor for the rudder plating as given in 3.1.1.3(2).

(2) In way of the recess for the rudder horn pintle on semi-spade rudders

① bending stress $\sigma_b$ 75 N/mm$^2$

② shear stress $\tau$ 50 N/mm$^2$

③ equivalent stress $\sigma_e=\sqrt{\sigma_b^2+3\tau^2}$ 100 N/mm$^2$

Note: The stresses in (2) apply equally to high tensile and ordinary steels.

3.1.5.2 Rudder plating

The thickness $t$ of the rudder side, top and bottom plating is not to be less than:

$$t=5.5s\beta\sqrt{K}\sqrt{d+C_R 10^{-4}/A}+2.5 \quad \text{mm}$$

where: $d$ — scantling draught, in m;

$C_R$ — rudder force, in N, according to 3.1.2.1 of this Section;

$A$ — rudder area, in m$^2$;

$\beta=\sqrt{1.1-0.5(\frac{s}{b})^2}$ max. 1.00 if $\frac{b}{s}\geq 2.5$;

$s$ — smallest unsupported width of plating, in m;

$b$ — greatest unsupported width of plating, in m;

$K$ — material factor for the rudder plating as given in 3.1.1.3(2).

The thickness of the nose plate of rudder blades is not to be less than 1.2 times that of rudder side plating, but need not be greater than 22 mm. The thickness of web plates is not to be less than the greater of 70% of the rudder side plating thickness and 8 mm.

The rudder plating in way of the solid part is to be of increased thickness per 3.1.5.3(4).

3.1.5.3 Connections of rudder blade structure with solid parts

(1) Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions.

These protrusions are not required when the web plate thickness is less than:

-10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders;

-20 mm for other web plates.

(2) The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

(3) Minimum section modulus of the connection with the rudder stock housing.

The section modulus of the cross-section of the structure of the rudder blade $W_s$, in cm$^3$, formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$W_s = c_s d_c^{\,3}\left(\frac{H_E - H_x}{H_E}\right)^2 \frac{K}{K_s}10^{-4} \quad \text{cm}^3$$

where: $c_s$ — coefficient, to be taken equal to:

= 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate;

= 1.5 if there is an opening in the considered cross-section of the rudder;

$d_c$ — diameter of rudder stock in way of lower bearing, in mm, calculated according to 3.1.4 of this Section;

$H_E$ — vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m;

$H_X$ — vertical distance between the considered cross-section and the upper edge of the solid part, in m;

$K$ — material factor for the rudder blade plating as given in 3.1.1.3(2);

$K_s$ — material factor for the rudder stock as given in 3.1.1.3(5).

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder. The breadth of the rudder plating, in m, to be considered for the calculation of section modulus is to be not greater than:

$$b = s_v + 2H_X / 3 \quad \text{m}$$

where: $s_v$ — spacing between the two vertical webs, in m (see Figure 3.1.5.3).

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

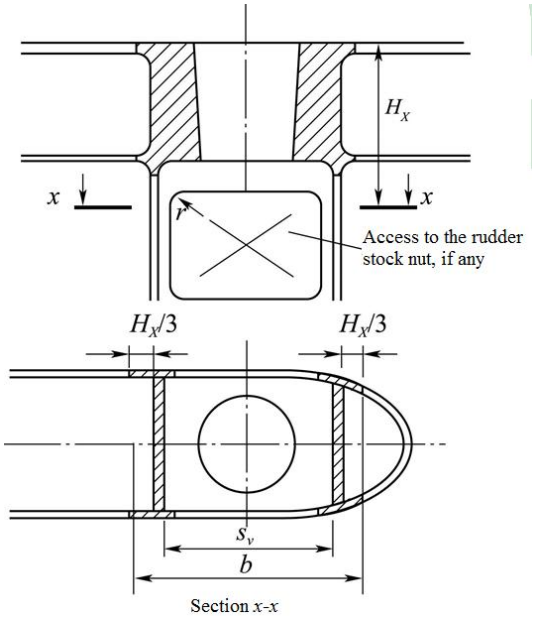



**Figure 3.1.5.3 Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown**

(4) The thickness of the horizontal web plates connected to the solid parts, in mm, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$$t_H = 1.2t \quad \text{mm}$$

$$t_H = 0.045 d_s^{\,2} / S_H \quad \text{mm}$$

where: $t$— defined in 3.1.5.2 of this Section;

$d_s$ — diameter, in mm, to be taken equal to:

= $d_c$, as per 3.1.4.2 of this Section, for the solid part housing the rudder stock;

=$d_p$, as per 3.1.7.1 of this Section, for the solid part housing the pintle;

$S_H$ — spacing between the two horizontal web plates, in mm.

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

(5) The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Table 3.1.5.3.

**Thickness of side plating and vertical web plates Table 3.1.5.3**

| Type of rudder | Thickness of vertical web plates, in mm | | Thickness of rudder plating, in mm | |
|---|---|---|---|---|
| | Rudder blade without opening | Rudder blade with opening | Rudder blade without opening | Area with opening |
| Rudder supported by sole piece | 1.2 t | 1.6 t | 1.2 t | 1.4 t |
| Semi-spade and spade rudders | 1.4 t | 2.0 t | 1.3 t | 1.6 t |

where: $t$ = thickness of the rudder plating, in mm, as defined in 3.1.5.2 of this Section.

The vertical web plates and rudder plating the thickness of which has been increased are to extend below the solid piece at least to the next horizontal web.

3.1.5.4 Single plate rudders

(1) Mainpiece diameter

The mainpiece diameter is calculated according to 3.1.4.1 and 3.1.4.2 of this Section respectively. For spade rudders the lower third may taper down to 0.75 times stock diameter.

(2) Blade thickness

The blade thickness $t$ is not to be less than:

$$t_b=1.5sV\sqrt{K}+2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffening arms, in m not to exceed 1 m;

$V$ — speed in knots, see 3.1.2.1(1) of this Section;

$K$ — material factor for the rudder plating as given in 3.1.1.3(2) of this Section.

(3) Arms

The thickness of the arms $t_a$ is not to be less than the blade thickness:

$$t_a=t_b \quad \text{mm}$$

The section modulus $W$ is not to be less than:

$$W=0.5sC_1^2V^2K \quad \text{cm}^3$$

where: $C_1$ — horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in m;

$K$ — material factor as given in 3.1.1.3(2) or 3.1.1.3 (5) of this Section respectively.

### 3.1.6 Rudder stock couplings

3.1.6.1 Horizontal flange couplings

(1) The diameter of the coupling bolts $d_b$ is not to be less than:

$$d_b=0.62\sqrt{d_s^3K_b/ne_mK_s} \quad \text{mm}$$

where: $d_s$ — stock diameter, taken equal to the greater of the diameters $d_t$ or $d_c$ according to 3.1.4.1 and 3.1.4.2, in mm;

$n$ — total number of bolts, which is not to be less than 6;

$e_m$ — mean distance, in mm, of the bolt axes from the centre of the bolt system;

$K_s$ — material factor for the stock as given in 3.1.1.3(5) of this Section;

$K_b$ — material factor for the bolts as given in 3.1.1.3(5) of this Section.

(2) The thickness of the coupling flanges $t_f$, in mm, is not to be less than the greater of the following formulae:

$$t_f=d_b\sqrt{K_f/K_b} \quad \text{mm}$$

$$t_f=0.9d_b \quad \text{mm}$$

where: $K_f$ — material factor for flange as given in 3.1.1.3(5) of this Section;

$K_b$ — material factor for the bolts as given in 3.1.1.3(5) of this Section;

$d_b$ — bolt diameter, in mm, calculated for a number of bolts not exceeding 8.

(3) The width of material between the perimeter of the bolt holes and the perimeter of the flange is not to be less than $0.677\,d_b$.

(4) The welded joint between the rudder stock and the flange is to be made in accordance with Figure 3.1.6.1 or equivalent.

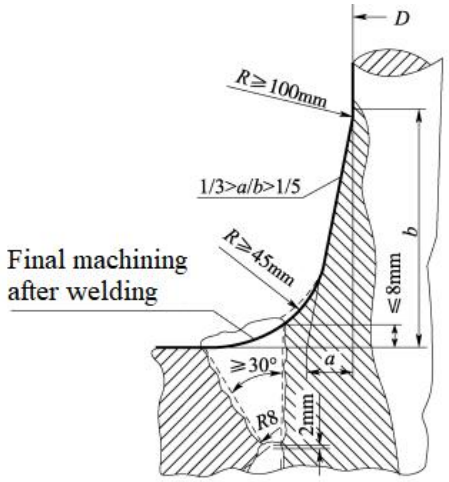



**Figure 3.1.6.1 Welded joint between rudder stock and coupling flange**

(5) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.2 Vertical flange couplings of rudder stock and rudder blades

(1) The diameter of the coupling bolts $d_b$, in mm, is not to be less than:

$$d_b = 0.81 d_s / \sqrt{n} \times \sqrt{K_b / K_s} \quad \text{mm}$$

where: $d_s$ — stock diameter [in mm] in way of coupling flange;

$n$ — total number of bolts, which is not to be less than 8;

$K_b$ — material factor for bolts as given in 3.1.1.3(5) of this Section;

$K_s$ — material factor for stock as given in 3.1.1.3(5) of this Section.

(2) The first moment of area of the bolts about the centre of the coupling, $m$, is to be not less than:

$$m = 0.00043 d_s^3 \quad \text{cm}^3$$

(3) The thickness of the coupling flanges is to be not less than the bolt diameter, and the width of the flange material between the perimeter of the bolt holes and the perimeter of the flange is to be not less than 0.67 $d_b$.

(4) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.3 Cone couplings with key

(1) Tapering and coupling length

Cone couplings without hydraulic arrangements for mounting and dismounting the coupling are to have a taper $c$ on diameter of 1:8 − 1:12.

Where $c = (d_0 - d_u) / l_c$, see Figure 3.1.6.3(a) and Figure 3.1.6.3(c).

The diameters $d_0$ and $d_u$ are shown in Figure 3.1.6.3(a) and the cone length, $l_c$, is defined in Figure 3.1.6.3(c).

The cone coupling is to be secured by a slugging nut. The nut is to be secured, e.g. by a securing plate as shown in Figure 3.1.6.3(a).

The cone shapes are to fit exactly. The coupling length $l$ is to be, in general, not less than $1.5d_0$.

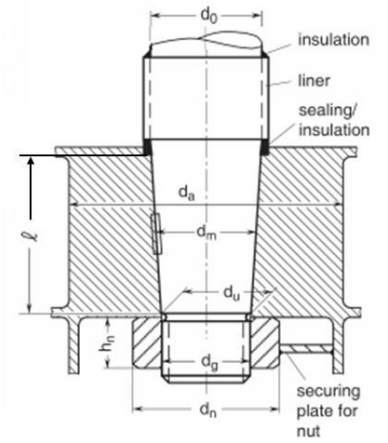



**Figure 3.1.6.3(a) Cone coupling with key**

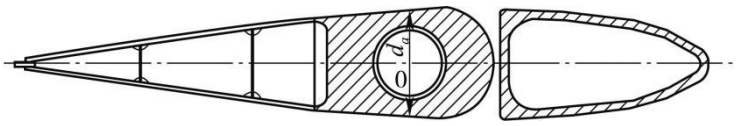



**Figure 3.1.6.3(b) Gudgeon outer diameter $d_a$**

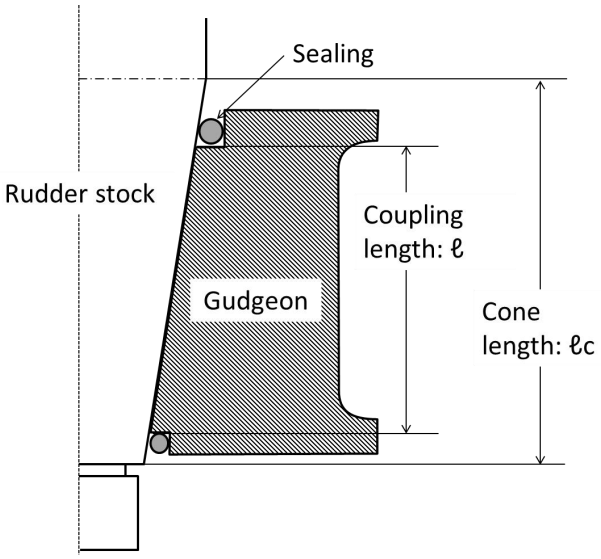



**Figure 3.1.6.3(c) Cone length and coupling length**

(2) Dimensions of key

For couplings between stock and rudder a key is to be provided, the shear area $a_s$ of which, in cm$^2$, is not to be less than:

$$a_s = \frac{17.55 Q_F}{d_k R_{eH1}} \quad \text{cm}^2$$

where:

$Q_F$ — design yield moment of rudder stock, in N·m;

$$Q_F = 0.02664 d_t^3 / K \quad \text{Nm}$$

Where the actual diameter $d_{ta}$ is greater than the calculated diameter $d_t$, the diameter $d_{ta}$ is to be used. However, $d_{ta}$ applied to the above formula need not be taken greater than 1.145 $d_t$.

$d_t$ — stock diameter, in mm, according to 3.1.4.1 of this Section;

$K$ — material factor for stock as given in 3.1.1.3(5) of this Section;

$d_k$ — mean diameter of the conical part of the rudder stock, in mm, at the key;

$R_{eH1}$ —specified minimum yield stress of the key material, in N/mm$^2$.

The effective surface area $a_k$, in cm$^2$, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 Q_F}{d_k R_{eH2}}$$

where: $R_{eH2}$ —specified minimum yield stress of the key, stock or coupling material, in N/mm$^2$.

(3) The dimensions of the slugging nut are to be as follows (see Figure 3.1.6.3(a)):

external thread diameter: $d_g \geq 0.65\, d_o$,

height: $h_n \geq 0.6\, d_g$,

outer diameter: $d_n \geq 1.2\, d_u$ or $1.5\, d_g$, whichever is the greater.

(4) It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 3.1.6.4(2) and 3.1.6.4(3) for a torsional moment $Q'_F = 0.5 Q_F$.

(5) Notwithstanding the requirements of 3.1.6.3(2) and 3.1.6.3(4), where a key is fitted to the coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be calculated according to the torque transmitted (not to be greater than the design yielding torque of the rudder stock.

3.1.6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

(1) Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, c ≈1:12 to ≈1:20.

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle.

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to 3.1.6.4(2) and 3.1.6.4(3) respectively.

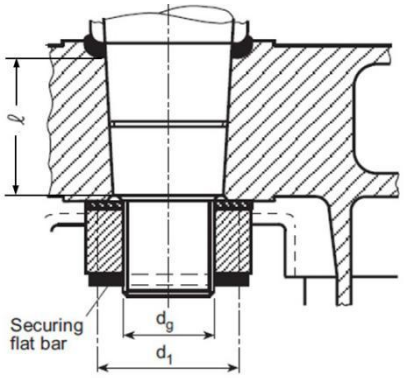



**Figure 3.1.6.4 Cone couplings without key**

(2) Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1}=\frac{2Q_F\times10^3}{d_m{}^2 l\pi\mu_0} \quad \text{N/mm}^2$$

$$p_{req2}=\frac{6M_c\times10^3}{l^2 d_m} \quad \text{N/mm}^2$$

where: $Q_F$ — design yield moment of rudder stock, as defined in 3.1.6.3(2) of this Section, in N·m;

$d_m$ — mean cone diameter, in mm, see Figure 3.1.6.3(a);

$l$ — coupling length, in mm;

$\mu_0$ — frictional coefficient, equal to 0.15;

$M_c$ — bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders), in N·m.

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure $p_{perm}$ , in N/mm², is to be determined by the following formula:

$$p_{perm}=\frac{0.95R_{eH}(1-\alpha^2)}{\sqrt{3+\alpha^4}}-p_b \quad \text{N/mm}^2$$

where: $p_b=\frac{3.5M_c\times10^3}{d_m l^2}$ N/mm²;

$R_{eH}$ — specified minimum yield stress of the material of the gudgeon, in N/mm²;

$\alpha=\frac{d_m}{d_a}$;

$d_m$ — diameter, in mm, see Figure 3.1.6.3(a);

$d_a$ — outer diameter of the gudgeon to be not less than 1.25 $d_0$, in mm, see Figure 3.1.6.3 (a) and 3.1.6.3(b). (The least diameter is to be considered).

(3) Push-up length

The push-up length $\Delta l$, in mm, is to comply with the following formula:

$$\Delta l_1 \le \Delta l \le \Delta l_2$$

where: $\Delta l_1=\frac{p_{req}d_m}{E\left(\frac{1-\alpha^2}{2}\right)c}+\frac{0.8R_{tm}}{c}$ mm

$$\Delta l_2 = \frac{p_{perm} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c} \quad \text{mm}$$

$R_{tm}$ — mean roughness, in mm, taken equal to 0.01;

$c$ — taper on diameter according to 3.1.6.4(1) of this Section, in mm;

Note: In case of hydraulic pressure connections the required push-up force $P_e$, in N, for the cone may be determined by the following formula:

$$P_e = p_{req} d_m \pi l \left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed. Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval.

### 3.1.7 Pintles

3.1.7.1 Scantlings

The pintle diameter $d_p$, in mm, is not to be less than:

$$d_p = 0.35\sqrt{BK_p} \quad \text{mm}$$

where: $B$ — relevant bearing force, in N;

$K_p$ — material factor for pintle as given in 3.1.1.3(5) of this Section.

3.1.7.2 Couplings

(1) Tapering

Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:

1:8 to 1:12 for keyed and other manually assembled pintles applying locking by slugging nut,

1:12 to 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.

(2) Push-up pressure for pintle

The required push-up pressure for pintle in case of dry fitting, in N/mm², is to be determined by $p_{req1}$ as given below.

The required push-up pressure for pintle in case of oil injection fitting, in N/mm², is to be determined by the maximum pressure of $p_{req1}$ and $p_{req2}$ as given below:

$$p_{req1} = 0.4\frac{Bd_0}{d_m^2 l} \quad \text{N/mm}^2$$

$$p_{req2} = \frac{6M_{bp}}{l^2 d_m} \times 10^3 \quad \text{N/mm}^2$$

where: $B$ — Supporting force in the pintle, in N;

$d_0$ — Pintle diameter, in mm, see Figure 3.1.6.3(a);

$M_{bp}$ ——bending moment in the pintle cone coupling to be determined by:

$$M_{bp} = Bl_a \quad \text{Nm}$$

$l_a$ ——length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, see Figure 3.1.7.2.

The push up length $\Delta l_1$ is to be calculated similarly as in 3.1.6.4(3) of this Section, using required push-up pressure and properties for the pintle.

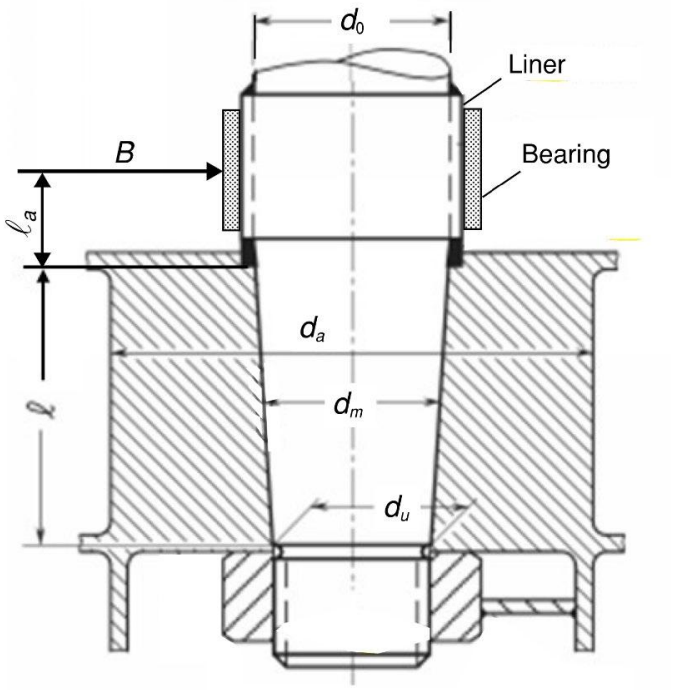



**Figure 3.1.7.2 Pintle cone coupling indicating $l_a$**

3.1.7.3 The minimum dimensions of threads and nuts are to be determined according to 3.1.6.3(3).

3.1.7.4 Pintle housing

The length of the pintle housing in the gudgeon is not to be less than the pintle diameter $d_p$. $d_p$ is to be measured on the outside of shaft sleeves.

The thickness of the pintle housing is not to be less than 0.25 $d_p$.

### 3.1.8 Rudder stock bearing, rudder shaft bearing and pintle bearing

3.1.8.1 Liners and bushes

(1) Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. The minimum thickness of liners and bushes $t_{min}$ is to be equal to:

$t_{min}$ = 8 mm for metallic materials and synthetic material;

$t_{min}$ = 22 mm for lignum material.

(2) Pintle bearing

The thickness of any liner or bush $t$, in mm, is not to be less than the minimum thickness defined in 3.1.8.1(1) and the following value:

$$t = 0.01\sqrt{B}$$

where: $B$— relevant bearing force, in N.

3.1.8.2 Minimum bearing surface

An adequate lubrication is to be provided.

The bearing surface $A_b$ (defined as the projected area: length × outer diameter of liner) is not to be less than:

$$A_b = \frac{P}{q_a} \quad \text{mm}^2$$

where: $P$ — reaction force, in N, in bearing as determined in 3.1.3.2 of this Section;

$q_a$ — allowable surface pressure according to Table 3.1.8.2.

The allowable surface pressure $q_a$ for the various combinations is to be taken as reported in the table below. Higher values than given in Table 3.1.8.2 may be taken in accordance with makers' specifications if they are verified by tests:

**Allowable surface pressure $q_a$** **Table 3.1.8.2**

| Bush material | $q_a$ (N/mm$^2$) |
|---|---|
| Lignum vitae | 2.5 |

| | |
|---|---|
| White metal, oil lubricated | 4.5 |
| Synthetic material with hardness greater than 60 Shore D① | 5.5② |
| Steel③ and bronze and hot-pressed bronze-graphite materials | 7.0 |

Notes:

① Indentation hardness test at 23 ℃ and with 50% moisture, are to be carried out according to a recognized standard. Synthetic bearing materials are to be of an approved type.

② Surface pressures exceeding 5.5 N/mm$^2$ may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm$^2$.

③ Stainless and wear-resistant steel in an approved combination with stock liner.

3.1.8.3 Bearing dimensions

The length/diameter ratio of the bearing surface is not to be greater than 1.2.

The bearing length $L_p$ of the pintle is to be such that $D_P \le L_P \le 1.2D_P$

where: $D_P$ —Actual pintle diameter measured on the outside of liners, in mm.

3.1.8.4 Bearing clearances

With metal bearings, clearances should not be less than $d$ / 1000 + 1.0 mm (where $d$ is the outer diameter of rudder stock or pintle) on the diameter. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is not to be taken less than 1.5 mm on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

### 3.1.9 Strength of rudder horns and rudder trunk

3.1.9.1 Rudder horns

The bending moments and shear forces are to be determined by a direct calculation or in line with the guidelines given in 2.4 and 2.5 of Appendix 1 for semi spade rudder with one elastic support and semi spade rudder with 2-conjugate elastic support respectively.

The section modulus around the horizontal $x$-axis $W$ is not to be less than:

$$W = M_b K / 67 \qquad \text{cm}^3$$

where: $M_b$ — bending moment at the section considered, in N·m.

The shear stress $\tau$ is not to be larger than:

$$\tau = 48 / K \qquad \text{N/mm}^2$$

where: $K$ — material factor as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

(1) Equivalent stress

At no section within the height of the rudder horn is the equivalent stress to exceed 120/$K$ N/mm$^2$. The equivalent stress $\sigma_v$ is to be calculated by the following formula:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)} \quad \text{N/mm}^2$$

where: $\sigma_b = M_b / Z_x$, in N/mm$^2$;

$Z_x$ — section modulus of rudder horn at the section considered, in cm$^3$;

$\tau = B_1 / A_h$, in N/mm$^2$;

$B_1$ — supporting force in the pintle bearing, in N;

$A_h$ — effective shear area of rudder horn in $y$-direction, in mm$^2$;

$\tau_T = M_T 10^3 / 2A_T t_h$, in N/mm$^2$;

$M_T$ — torsional moment, in N·m;

$A_T$ — area in the horizontal section enclosed by the rudder horn, in mm$^2$;

$t_h$ — plate thickness of rudder horn, in mm;

(2) Rudder horn plating

The thickness of the rudder horn side plating $t$ is not to be less than:

$$t = 2.4\sqrt{LK} \quad \text{mm}$$

where: $L$ — length of the ship, in m;

$K$ — material factor, as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section respectively.

(3) Welding and connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/ longitudinal girders, in order to achieve a proper transmission of forces, see Figure 3.1.9.1.
If the connection of rudder horn and hull structure is so designed that the rudder horn is transited to hull plating in the curved way, particular attention is to be made to the effectiveness of the bending of rudder horn and the stress of transverse webs.
Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Figure 3.1.9.1.

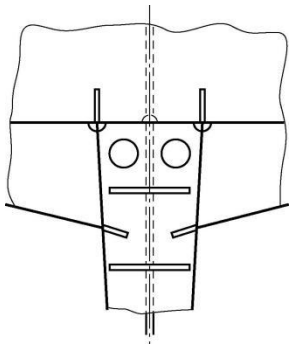


**Figure 3.1.9.1 Connection of rudder horn to aft ship structure**

Transverse webs of the rudder horn are to be led into the hull up to the next platform deck in a sufficient number.
Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.
The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.
Scallops are to be avoided in way of the connection between transverse webs and shell plating.
The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

3.1.9.2 Rudder trunk

The requirements in this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

(1) Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent $C_{EQ}$ not exceeding 0.41%.
Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in Section 3, Chapter 1 of this PART.
The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.
For rudder trunks extending below shell or skeg, the fillet shoulder radius $r$, in mm (see Figure 3.1.9.2) is to be as large as practicable and to comply with the following formulae:

$r = 0.1 d_c / K$, without being less than:

$r$ =60 mm when $\sigma \geq 40/K$ N/mm$^2$
$r$ = 30 mm when $\sigma < 40/K$ N/mm$^2$

where: $d_c$ — rudder stock diameter axis as defined in 3.1.4.2;
$\sigma$ — bending stress in the rudder trunk, in N/mm$^2$;
$K$ — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.
The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.
Rudder trunks comprising of materials other than steel are to be specially considered.

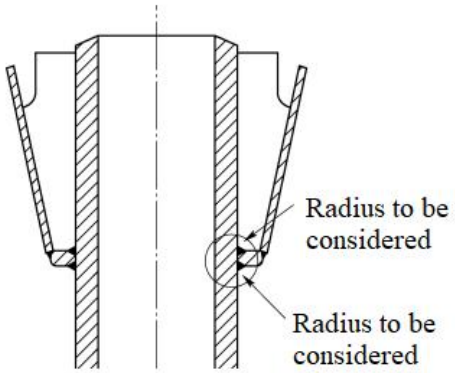



**Figure 3.1.9.2**

(2) Scantlings

The scantlings of the trunk are to be such that: the equivalent stress due to bending and shear does not exceed 0.35 $R_{eH}$.

The bending stress on welded rudder trunk $\sigma$ is to be in compliance with the following formula:

$$\sigma \leqslant 80/K \quad \text{N/mm}^2$$

where: $\sigma$ — bending stress in the rudder trunk, as defined in 3.1.9.2(1);

$K$ — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section, not to be taken as less than 0.7;

$R_{eH}$ —specified minimum yield stress, in N/mm$^2$, of the material used.

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

### 3.1.10 Others

3.1.10.1 Quadrants and tillers

(1) The section modulus $W$ of the tiller at any section from the centre of the rudder stock about the vertical axis is not to be less than that obtained from the following formula:

$$W = 0.14(1-\frac{D_S}{R})D_t^3(K_t/K_s) \quad \text{mm}^3$$

where: $D_S$ — distance from the section under consideration to the centerline of the stock on the tiller, not greater than the bore diameter of the pin, in mm, see Figure 3.1.10.1;

$D_t$ — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

$R$ — radius of quadrant or length of tiller, in mm;

$K_t$ — material factor of tiller, see 3.1.1.3(5) of this Section;

$K_s$ — material factor of stock, see 3.1.1.3(5) of this Section.

For quadrants having more than one arm, the combined section modulus of the arms is not to be less than that required in the above formula.

For tillers of rectangular section, the breadth to depth ratio is not to be more than 2.

(2) Depth of boss of the quadrant or tiller $h \geq 1.0\ D_t$, and its outside diameter $D_0 \geq 1.8\ D_t$, see Figure 3.1.10.1. Where the depth of boss of the tiller $h$ is greater than $D_t$, the required outer diameter $D_0$ may be reduced accordingly. It is to ensure that $h \times D_0^2 \geq 3.24 D_t^3$, and $D_0$ is not to be less than 1.6 $D_t$ in any case. $D_t$ is defined in (1) above.

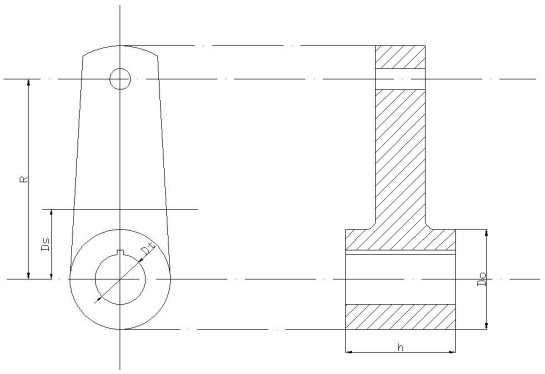



**Figure 3.1.10.1**

(3) Where the boss of a tiller (quadrant) is composed of two half pieces, at least one key is to be fitted and each end of the key is to be secured by at least 2 bolts. The bolts are to be pretightened and the prestressing force on each bolt is to correspond to 70% of the permissible stress of bolt material. Where double keys are used, the prestressing force may be reduced appropriately. The total cross-sectional area $A_b$ of all bolts is not to be less that obtained from the following formula:

$$A_b = 0.2 \times \frac{D_t^3}{b}(K_b/K_s) \quad \text{mm}^2$$

where: $D_t$ — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

$b$ — distance between centerlines of bolt at both ends, in mm;

$K_b$ — material factor of bolt, see 3.1.1.3(5) of this Section;

$K_s$ — material factor of stock, see 3.1.1.3(5) of this Section.

(4) The cross-sectional area $A_r$ and moment of inertia $I_r$ of the rod connecting the tiller (quadrant) to the tiller are not to be less than those obtained from the following formulas:

$$A_r = 0.12 \times \frac{D_t^3}{R}(K_r / K_s) \quad \text{mm}^2$$

$$I_r = 6.6 \frac{D_t^3 l^2}{R} \times 10^{-6}(K_r / K_s) \quad \text{mm}^4$$

where: $D_t$ — diameter of the rudder stock, at the tiller of a passive rudder, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

$l$ — length of the connecting rod, in mm;

$R$ — length of the tiller of the passive rudder, in mm;

$K_r$ — material factor of connecting rod, see 3.1.1.3(5) of this Section;

$K_s$ — material factor of stock, see 3.1.1.3(5) of this Section.

(5) For a rotary vane type steering gear, the rotor and blades of the gear are to comply with the requirements of 3.1.10.1(1) and 3.1.10.1(2) for boss of the tiller and the tiller.

3.1.10.2 Connection of rudder tiller to stock

(1) The connection of the rudder tiller to stock is to be such that mechanical forces are transmitted from the steering gear to the rudder stock in any operational condition. The torque $T_d$ transmitted by such connection is not to be less than twice the design torque of the steering gear, but need not be greater than the design yield torque $Q_F$ of the stock calculated according to 3.1.6.3(2) of this Section. The design torque of the steering gear is corresponding to the design pressure in 13.1.6.5 of Chapter 13, PART THREE of the Rules.

(2) For torque transmission by friction, the average surface pressure $p_r$ for the connection of tiller to stock is not to be less than that obtained from the following formula:

$$p_r \geq \frac{2T_{fr}}{\pi D_m^2 l f} \times 10^3 \quad \text{N/mm}^2$$

where: $T_{fr}$ — torque transmitted by friction, in N·m;

= $T_d$, for keyless connection;

= $0.5T_d$, for keyed connection;

$T_d$ — torque transmitted through connection of tiller to stock, in N·m, determined according to 3.1.10.2(1) of this Section;

$D_m$ — diameter of the rudder stock or mean diameter of the taper, in mm;

$l$ — length of the effectively connected portion of the tiller, in mm;

$f$ — coefficient of friction, taken as 0.15 for hydraulic fit or 0.18 for dry fit.

(3) For conical connection, nuts are to be used for securing against axial displacement. It is to be ensured that the size of nuts is to sustain the weight of rudder and rudder stock without considering the force of friction between rudder tiller and rudder stock, and reference may be made to the requirements of 3.1.6.3(3) of this Section.

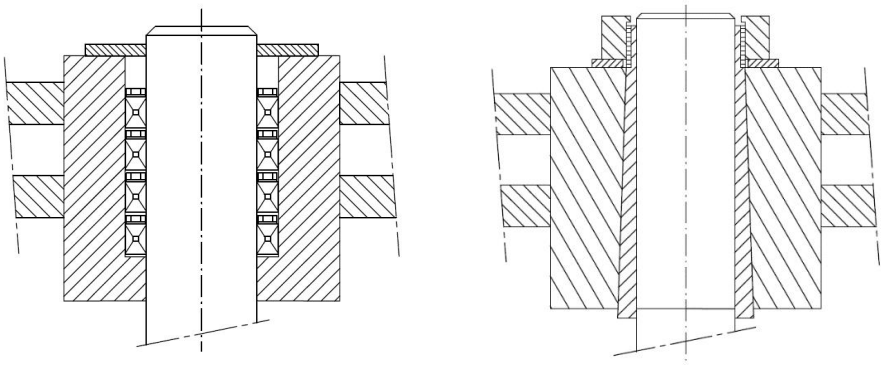
(4) Where the tiller is connected to the stock by means of several expansion sleeves or conical sleeves, as indicated in Figure 3.1.10.2, the influence of axial forces is also to be taken into account. In this case, the torque $T_{d1}$ transmitted by the connection of tiller to stock is not to be less than that obtained from the following formula:

$$T_{d1}=\sqrt{T_d^2+(2\cdot W\cdot D_m)^2\cdot 10^{-4}} \quad \text{N·m}$$

where: $T_d$ — torque, in N·m, determined according to 3.1.10.2(1) of this Section;

$W$ — weight of rudder and rudder stock, in kg;

$D_m$ — diameter of rudder stock, in mm.



(a) Expansion sleeve (b) Conical sleeve

**Figure 3.1.10.2**

(5) The taper of cone on diameter is to be not greater than 1:15 for keyless conical connection and not greater than 1:10 for keyed conical connection.

(6) For keyed connection, the shear area $As$ of the key is not to be less than that obtained from the following formula:

$$A_s=\frac{70\left(T_d-k_{key}T_{fr}\right)}{D_k R_{eH}} \quad \text{cm}^2$$

where: $T_d$ — torque transmitted through connection of tiller to stock, in N·m, calculated according to 3.1.10.2 of this Section;

$k_{key}$ — coefficient, determined as follows:

= 0.7 where boss of tiller is composed of two half pieces and secured by bolts;

= 0.9 for hydraulic fitting of tiller to stock;

= 1.0 in other cases.

$T_{fr}$ — torque transmitted by friction, in N·m, calculated according to the following formula:

$$T_{fr}=\frac{\pi p_r D_m^2 l f}{2}\times 10^{-3}$$

where: $p_r$ — average surface pressure for the connection of tiller to stock, in N/mm$^2$, determined according to 3.1.10.2(2) of this Section. Where hydraulic fitting or shrinkage fit is adopted for the conical connection, the average push-up surface pressure is to be taken;

$D_m$, $l$, $f$ — same as in 3.1.10.2(2) of this Section;

$D_k$ — mean diameter, in mm, of rudder stock cone in way of the position where the key is fitted;

$R_{eH}$ — yield stress, in N/mm$^2$, of key material.

(7) For keyed connections, the compressed area $A_k$ of keys (round edge portion not included) is not to be less than that obtained from the following formula:

$$A_k=\frac{22\left(T_d-k_{key}T_{fr}\right)}{D_k R_{eH}} \quad \text{cm}^2$$

where: $T_d$ , $k_{key}$, $T_{fr}$ , $D_k$ — same as in (6) above;

$R_{eH}$ — yield stress, in N/mm$^2$, of key material.

(8) Where two keys are fitted, the shear area $A_s$ and compressed area $A_k$ of each key may be taken as 2/3 of the value obtained for one key.
(9) The keyway is to have an adequately rounded end. The radius of curvature is usually not to be less than 5% of the thickness of the key. The compressive stress on the stock/tiller keyway is not to exceed 90% of the yield stress of the material used.
(10) Where the hydraulic fitting or shrinkage fit is adopted for the conical connection, the push-up length and the average push-up surface pressure are to be determined in accordance with the following requirements:

① The push-up length $S$ is to meet the following:

$$S_1 \leq S \leq S_2$$

The minimum push-up length $S_1 = \frac{1}{k_1}[\frac{2p_r D_m k_2^2}{E(k_2^2 - 1)} + 0.02]$ mm

The maximum push-up length $S_2 = \frac{1}{k_1}[1.6R_{eH}D_m \frac{k_2^2}{E\sqrt{3k_2^4 + 1}} + 0.02]$ mm

where: $p_r$ — average surface pressure for the connection of tiller to stock, in N/mm$^2$, determined according to 3.1.10.2(2) of this Section;
$k_1$ — taper of cone on diameter;
$k_2 = (D_m + 2t_a) / D_m$;
$D_m$ — mean diameter of cone, in mm;
$t_a$ — mean thickness of boss of tiller, in mm;
$R_{eH}$ — yield stress of material of boss of tiller or rudder stock, whichever is less, in N/ mm$^2$;
$E$ — elastic modulus, to be taken as $2.06 \times 10^5$, in N/mm$^2$.

② The average push-up surface pressure $P$ is to be calculated by the following formula:

$$P = \frac{SE(k_2^2 - 1)k_1}{2D_m k_2^2} \quad \text{N/ mm}^2$$

where: $k_1$, $k_2$, $D_m$ and $E$ — same as in ① above;
$S$ — the push-up length to be determined in accordance with ① above, in mm.

3.1.10.3 Strengthening for navigation in ice
(1) For ships with Ice Class notations the scantlings and arrangement of the rudder structures are to comply with the relevant requirements of Chapter 4 of this PART.

# Section 2 ANCHORING AND MOORING EQUIPMENT

### 3.2.1 Equipment number

3.2.1.1 The anchoring equipment for sea-going ships are to be provided in accordance with Tables 3.2.1.1(1) and 3.2.1.1(2), based on the ship type and service area as well as the equipment number derived from 3.2.1.2 of this Section. Requirements of this Section for the number, length and breaking loads of towlines and mooring lines are only as guidance.
For non-self-propelled ships engaged in special work, of which an increased mass of anchors is required by the owner and anchoring operations are carried out by means of other appliances, chain cables may be provided in accordance with the rule requirements for the mass of anchors only.
The requirement for the anchoring equipment in this Section is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.
The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.
The anchoring equipment presently required in this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.
The Equipment Numeral (EN) formula for anchoring equipment required in this Section is based on an assumed maximum current speed of 2.5 m/sec, maximum wind speed of 25 m/sec and a minimum scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth. For ships with an equipment length greater than 135 m, alternatively the required anchoring equipment can

be considered applicable to a maximum current speed of 1.54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m.
It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.
Manufacture of anchors and anchor chain cables is to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.
The bower anchor is to be connected with its chain cable, arranged onboard the ship and ready for use.
In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of maneuverability, unscheduled repairs and other unexpected situations.

**Equipment Required Table 3.2.1.1(1)**

| Ship type | Required equipment |
|---|---|
| Cargo ships, bulk carriers, oil tankers, trailing suction dredgers, ferries, etc. | Using *N* |
| Tugs | Using *N* |
| Offshore supply ships | Using *N*, but the chain cables are to be selected 2 grades above *N* |
| Manned barges | Using *N* |
| Unmanned barges | Using *N*, but only one bower anchor is required, and 0.5 times the length of chain cables required for *N* may be provided |
| Floating cranes, floating pile drivers or other similar workboats | Using *N*, but side projections of the crane, pile driver, etc., are to be considered for *N*. If the anchors used comply with the requirements of this Table, they may be used in lieu of bower anchors. |

3.2.1.2 The equipment number *N* is to be obtained from the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(Bh + S_{fun}) + \frac{A}{10}$$

where: $\Delta$ — moulded displacement, in t, to the summer load waterline;
$B$ — moulded breadth, in m;
$h$ — effective height, in m, from the summer load waterline to the top of the uppermost house, i.e.:

$$h = a + \sum h_i$$

where: $a$ — vertical distance at hull side, in m, measured from the summer load waterline amidships to the upper deck;
$h_i$ — height at the centreline, in m, of each tier of houses having a breadth greater than $B/4$; for the lowest tier $h_1$ is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Figure 3.2.1.1(1);
$A$ — area, in m², in profile view of the hull, within the length of the vessel, and of superstructures and deckhouses and funnels above the summer load waterline, which are within the length of the vessel, and also having a breadth greater than $B/4$. The side projected area of the funnel is considered in $A$ when $A_{FS}$ is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height $h_F$;
$S_{fun}$ — effective front projected area of the funnel, in m², defined as:

$$S_{fun} = A_{FS} - S_{shield}$$

where: $A_{FS}$ — front projected area of the funnel, in m², calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height $h_F$. $A_{FS}$ is taken

equal to zero if the funnel breadth is less than or equal to $B/4$ at all elevations along the funnel height;

$h_F$— effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches B/4;

$S_{shield}$ — the section of front projected area $A_{FS}$, in m², which is shielded by all deck houses having breadth greater than $B/4$. If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield\ 2}$ etc as shown in Figure 3.2.1.2(3) to be added together. To determine $S_{shield}$, the deckhouse breadth is assumed $B$ for all deck houses having breadth greater than $B/4$ as shown for $S_{shield1}$, $S_{shield2}$ in Figure 3.2.1.2(3). When several funnels are fitted on the ship, the above parameters are taken as follows:

$h_F$— effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches $B/4$;

$A_{FS}$ — sum of the front projected area of each funnel, in m², calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height $h_F$. $A_{FS}$ is to be taken equal to zero if the sum of each funnel breadth is less than or equal to $B/4$ at all elevations along the funnels height;

$A$ — Side projected area, in m$^2$, of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, $A$, when $A_{FS}$ is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

The equipment number of tugs is to be determined by the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(aB + \sum b_i\ h_i) + \frac{A}{10}$$

where: $a$, $B$ and $h_i$ — same as defined above;

$b_i$ — breadth, in m, of superstructures or of deckhouses of each tier having a breadth greater than $B/4$.

For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard.

In the calculation of $h$ and $A$, sheer and trim are to be ignored, i.e. $h$ is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than B/4.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

If a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less then the wide house is to be included but the narrow house ignored.

The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining $h$ and $A$. With regard to determining $A$, when a bulwark is more than 1.5 m high, the area shown as $A_2$ in Figure 3.2.1.2(2) is to be included in $A$. The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

For ships of length less than 90 m, alternative methodology using direct force calculation for anchoring equipment described in appendix 3 of this Chapter may be used.

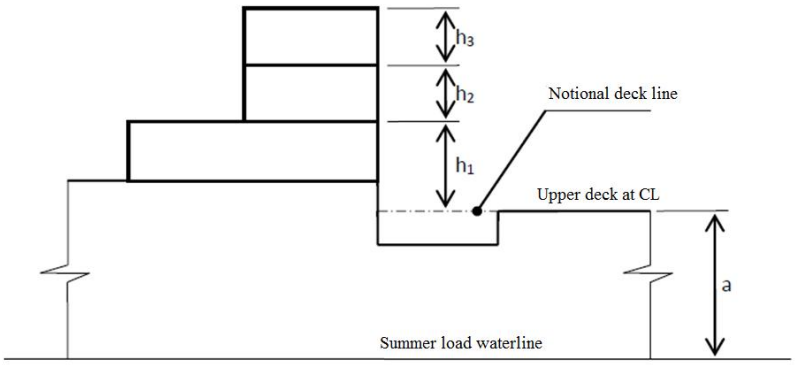



**Figure 3.2.1.2(1)**

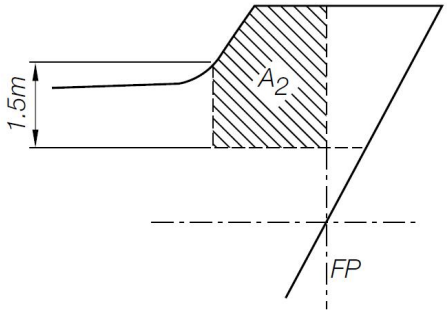



**Figure 3.2.1.2(2)**

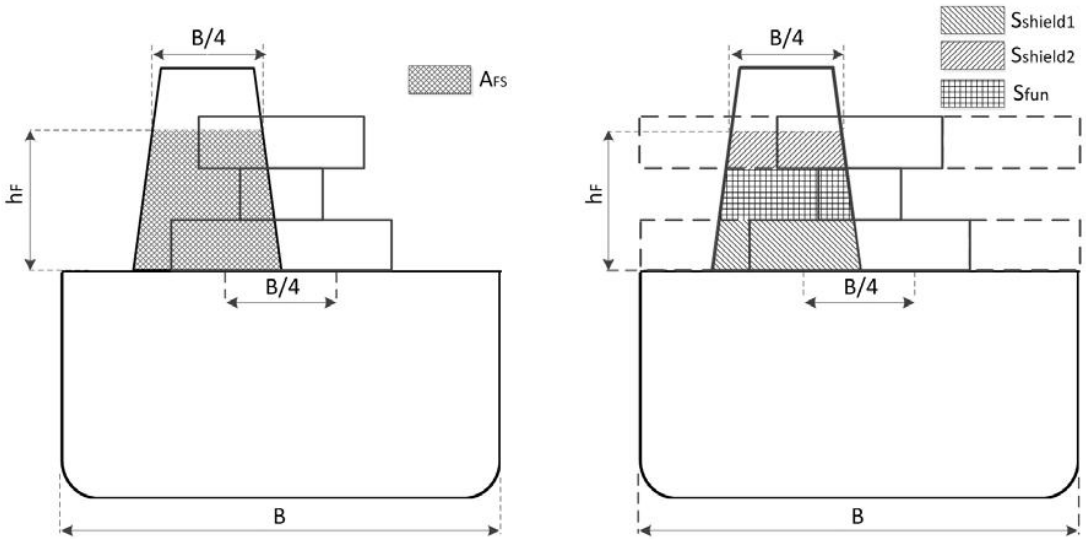



**Figure 3.2.1.2(3)**

### 3.2.2 Anchors

3.2.2.1 The mass of individual bower anchors may vary within -7% to +7% of the mass given in Table 3.2.1.1(2) of this Section, provided that the total mass of the bower anchors is not to be less than that would have been required for anchors of equal mass.

3.2.2.2 The mass of the head, including pins and swivels, of an ordinary stockless anchor is not to be less than 60% of the total mass of the anchor.

3.2.2.3 Stocked bower anchors may be used, but the mass excluding the stock is not to be less than 80% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors.

3.2.2.4 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors. When

super high holding power anchors of the proven holding power are used as bower anchors, the mass of each such anchor may be reduced to not less than 50% of the mass required for ordinary stockless anchors in Table 3.2.1.1(2) of this Section. See specific requirements of Section 1, Chapter 10 of PART ONE of CCS Rules for Materials and Welding.

**Anchoring and Towing Equipment** **Table 3.2.1.1(2)**

| Serial No. | Equipment No. N | | Bower anchors | | Stud link chain cable for bower anchors | | | | Towlines | | Mooring lines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exceeding | Not exceeding | Number | Mass of each anchor (kg) | Total length (m) | Diameter | | | Min. length (m) | Ship design Min. breaking load (kN) | Number | Min. length each (m) | Ship design Min. breaking load (kN) |
| | | | | | | Grade 1 | Grade 2 | Grade 3 | | | | | |
| 1 | 50 | 70 | 2 | 180 | 220 | 14 | 12.5 | | 180 | 98 | 3 | 80 | 37 |
| 2 | 70 | 90 | 2 | 240 | 220 | 16 | 14 | | 180 | 98 | 3 | 100 | 40 |
| 3 | 90 | 110 | 2 | 300 | 247.5 | 17.5 | 16 | | 180 | 98 | 3 | 110 | 42 |
| 4 | 110 | 130 | 2 | 360 | 247.5 | 19 | 17.5 | | 180 | 98 | 3 | 110 | 48 |
| 5 | 130 | 150 | 2 | 420 | 275 | 20.5 | 17.5 | | 180 | 98 | 3 | 120 | 53 |
| 6 | 150 | 175 | 2 | 480 | 275 | 22 | 19 | | 180 | 98 | 3 | 120 | 59 |
| 7 | 175 | 205 | 2 | 570 | 302.5 | 24 | 20.5 | | 180 | 112 | 3 | 120 | 64 |
| 8 | 205 | 240 | 2 | 660 | 302.5 | 26 | 22 | 20.5 | 180 | 129 | 4 | 120 | 69 |
| 9 | 240 | 280 | 2 | 780 | 330 | 28 | 24 | 22 | 180 | 150 | 4 | 120 | 75 |
| 10 | 280 | 320 | 2 | 900 | 357.5 | 30 | 26 | 24 | 180 | 174 | 4 | 140 | 80 |
| 11 | 320 | 360 | 2 | 1020 | 357.5 | 32 | 28 | 24 | 180 | 207 | 4 | 140 | 85 |
| 12 | 360 | 400 | 2 | 1140 | 385 | 34 | 30 | 26 | 180 | 224 | 4 | 140 | 96 |
| 13 | 400 | 450 | 2 | 1290 | 385 | 36 | 32 | 28 | 180 | 250 | 4 | 140 | 107 |
| 14 | 450 | 500 | 2 | 1440 | 412.5 | 38 | 34 | 30 | 180 | 277 | 4 | 140 | 117 |
| 15 | 500 | 550 | 2 | 1590 | 412.5 | 40 | 34 | 30 | 190 | 306 | 4 | 160 | 134 |
| 16 | 550 | 600 | 2 | 1740 | 440 | 42 | 36 | 32 | 190 | 338 | 4 | 160 | 143 |
| 17 | 600 | 660 | 2 | 1920 | 440 | 44 | 38 | 34 | 190 | 370 | 4 | 160 | 160 |
| 18 | 660 | 720 | 2 | 2100 | 440 | 46 | 40 | 36 | 190 | 406 | 4 | 160 | 171 |
| 19 | 720 | 780 | 2 | 2280 | 467.5 | 48 | 42 | 36 | 190 | 441 | 4 | 170 | 187 |
| 20 | 780 | 840 | 2 | 2460 | 467.5 | 50 | 44 | 38 | 190 | 479 | 4 | 170 | 202 |
| 21 | 840 | 910 | 2 | 2640 | 467.5 | 52 | 46 | 40 | 190 | 518 | 4 | 170 | 218 |
| 22 | 910 | 980 | 2 | 2850 | 495 | 54 | 48 | 42 | 190 | 559 | 4 | 170 | 235 |
| 23 | 980 | 1060 | 2 | 3060 | 495 | 56 | 50 | 44 | 200 | 603 | 4 | 180 | 250 |
| 24 | 1060 | 1140 | 2 | 3300 | 495 | 58 | 50 | 46 | 200 | 647 | 4 | 180 | 272 |
| 25 | 1140 | 1220 | 2 | 3540 | 522.5 | 60 | 52 | 46 | 200 | 691 | 4 | 180 | 293 |
| 26 | 1220 | 1300 | 2 | 3780 | 522.5 | 62 | 54 | 48 | 200 | 738 | 4 | 180 | 309 |
| 27 | 1300 | 1390 | 2 | 4050 | 522.5 | 64 | 56 | 50 | 200 | 786 | 4 | 180 | 336 |
| 28 | 1390 | 1480 | 2 | 4320 | 550 | 66 | 58 | 50 | 200 | 836 | 4 | 180 | 352 |
| 29 | 1480 | 1570 | 2 | 4590 | 550 | 68 | 60 | 52 | 220 | 888 | 5 | 190 | 352 |
| 30 | 1570 | 1670 | 2 | 4890 | 550 | 70 | 62 | 54 | 220 | 941 | 5 | 190 | 362 |
| 31 | 1670 | 1790 | 2 | 5250 | 577.5 | 73 | 64 | 56 | 220 | 1024 | 5 | 190 | 384 |
| 32 | 1790 | 1930 | 2 | 5610 | 577.5 | 76 | 66 | 58 | 220 | 1109 | 5 | 190 | 411 |

| Serial No. | Equipment No. N | | Bower anchors | | Stud link chain cable for bower anchors | | | | Towlines | | Mooring lines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exceeding | Not exceeding | Number | Mass of each anchor (kg) | Total length (m) | Diameter | | | Min. length (m) | Ship design Min. breaking load (kN) | Number | Min. length each (m) | Ship design Min. breaking load (kN) |
| | | | | | | Grade 1 | Grade 2 | Grade 3 | | | | | |
| 33 | 1930 | 2080 | 2 | 6000 | 577.5 | 78 | 68 | 60 | 220 | 1168 | 5 | 190 | 437 |
| 34 | 2080 | 2230 | 2 | 6450 | 605 | 81 | 70 | 62 | 240 | 1259 | | | |
| 35 | 2230 | 2380 | 2 | 6900 | 605 | 84 | 73 | 64 | 240 | 1356 | | | |
| 36 | 2380 | 2530 | 2 | 7350 | 605 | 87 | 76 | 66 | 240 | 1453 | | | |
| 37 | 2530 | 2700 | 2 | 7800 | 632.5 | 90 | 78 | 68 | 260 | 1471 | | | |
| 38 | 2700 | 2870 | 2 | 8300 | 632.5 | 92 | 81 | 70 | 260 | 1471 | | | |
| 39 | 2870 | 3040 | 2 | 8700 | 632.5 | 95 | 84 | 73 | 260 | 1471 | | | |
| 40 | 3040 | 3210 | 2 | 9300 | 660 | 97 | 84 | 76 | 280 | 1471 | | | |
| 41 | 3210 | 3400 | 2 | 9900 | 660 | 100 | 87 | 78 | 280 | 1471 | | | |
| 42 | 3400 | 3600 | 2 | 10500 | 660 | 102 | 90 | 78 | 280 | 1471 | | | |
| 43 | 3600 | 3800 | 2 | 11100 | 687.5 | 105 | 92 | 81 | 300 | 1471 | | | |
| 44 | 3800 | 4000 | 2 | 11700 | 687.5 | 107 | 95 | 84 | 300 | 1471 | | | |
| 45 | 4000 | 4200 | 2 | 12300 | 687.5 | 111 | 97 | 87 | 300 | 1471 | | | |
| 46 | 4200 | 4400 | 2 | 12900 | 715 | 114 | 100 | 87 | 300 | 1471 | | | |
| 47 | 4400 | 4600 | 2 | 13500 | 715 | 117 | 102 | 90 | 300 | 1471 | | | |
| 48 | 4600 | 4800 | 2 | 14100 | 715 | 120 | 105 | 92 | 300 | 1471 | | | |
| 49 | 4800 | 5000 | 2 | 14700 | 742.5 | 122 | 107 | 95 | 300 | 1471 | | | |
| 50 | 5000 | 5200 | 2 | 15400 | 742.5 | 124 | 111 | 97 | 300 | 1471 | | | |
| 51 | 5200 | 5500 | 2 | 16100 | 742.5 | 127 | 111 | 97 | 300 | 1471 | | | |
| 52 | 5500 | 5800 | 2 | 16900 | 742.5 | 130 | 114 | 100 | 300 | 1471 | | | |
| 53 | 5800 | 6100 | 2 | 17800 | 742.5 | 132 | 117 | 102 | 300 | 1471 | | | |
| 54 | 6100 | 6500 | 2 | 18800 | 742.5 | | 120 | 107 | | | | | |
| 55 | 6500 | 6900 | 2 | 20000 | 770 | | 124 | 111 | | | | | |
| 56 | 6900 | 7400 | 2 | 21500 | 770 | | 127 | 114 | | | | | |
| 57 | 7400 | 7900 | 2 | 23000 | 770 | | 132 | 117 | | | | | |
| 58 | 7900 | 8400 | 2 | 24500 | 770 | | 137 | 122 | | | | | |
| 59 | 8400 | 8900 | 2 | 26000 | 770 | | 142 | 127 | | | | | |
| 60 | 8900 | 9400 | 2 | 27500 | 770 | | 147 | 132 | | | | | |
| 61 | 9400 | 10000 | 2 | 29000 | 770 | | 152 | 132 | | | | | |
| 62 | 10000 | 10700 | 2 | 31000 | 770 | | | 137 | | | | | |
| 63 | 10700 | 11500 | 2 | 33000 | 770 | | | 142 | | | | | |
| 64 | 11500 | 12400 | 2 | 35500 | 770 | | | 147 | | | | | |
| 65 | 12400 | 13400 | 2 | 38500 | 770 | | | 152 | | | | | |
| 66 | 13400 | 14600 | 2 | 42000 | 770 | | | 157 | | | | | |
| 67 | 14600 | 16000 | 2 | 46000 | 770 | | | 162 | | | | | |

### 3.2.3 Chain cables

3.2.3.1 For ships with $N$ less than 90, chain cables may be substituted by studless chains of equivalent proof-load.
3.2.3.2 Wire rope may be used in place of chain cable on ships subject to the following conditions:
(1) with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or
(2) with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.
(3) for anchors used for operation of floating cranes, floating pile drivers or other similar workboats as specified in Table 3.2.1.1(1).
3.2.3.3 Use of wire rope is subject to the following conditions:
(1) The wire ropes are to have a total length equal to 1.5 times the corresponding length of stud link chain cables required in Table 3.2.1.1(2), and a minimum breaking load equal to that given for the corresponding stud link chain cable of Grade 1.
(2) The anchor weight shall be increased by 25 % compared to anchor associated with chain cable according to Table 3.2.1.1(2).
(3) A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.
(4) All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).
(5) Steel wire shall be selected to fit for purpose based on the manufacturer recommendation and shall be provided with guidance for maintenance and inspection.
3.2.3.4 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected.
3.2.3.5 The inboard end of the chain cables is to be secured to the hull structure and so arranged that they will be capable of being immediately released from a position easily accessible outside the chain locker.
3.2.3.6 Grade 1 material having a tensile stress of less than 400 N/mm² is not to be used in association with high holding power anchors. Grade 3 material is to be used only for chains of 20.5 mm or more in diameter.
3.2.3.7 The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

### 3.2.4 Towlines and mooring lines

3.2.4.1 The number, length and breaking loads of mooring lines are to be marked on the mooring arrangement plan of the ship. The towlines listed in Table 3.2.1.1(2) are provided on board for the tug or for the use by other ships towing the ship. The lateral projected area of deck cargoes as given by the ship nominal capacity condition is to be taken into account during the calculation of equipment number for selection of towing lines. As an alternative method to 3.2.4, the number and strength of mooring lines may be determined by means of direct mooring analysis of Appendix 2 of this Chapter.
3.2.4.2 Mooring lines for ships with EN $\leqslant$ 2000 are to be determined according to Table 3.2.1.1(2). For ships having the ratio A/N > 0.9, number of lines given in Table 3.2.1.1(2) is to be added to the number of mooring lines according to the following formulae:

One line where $0.9 < \frac{A}{\mathrm{N}} \leq 1.1$

two lines where $1.1 < \frac{A}{\mathrm{N}} \leq 1.2$

three lines where $1.2 < \frac{A}{\mathrm{N}}$

3.2.4.3 The strength of mooring lines and the number of head, stern, and breast lines (see Figure 3.2.4.2) for ships with an Equipment Number EN > 2000 are based on the side-projected area $A_1$. Side projected area $A_1$ is to be calculated similar to the side-projected area A according to 3.2.1.2 but considering the following conditions:
Ballast draft is to be considered for the calculation of the side-projected area $A_1$. For ship types with small change of draft, e.g. passenger ships and ro-ro ships, the summer load waterline may be used for the calculation of the side-projected area $A_1$.
Wind shielding of the pier can be considered for the calculation of the side-projected area $A_1$ unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline

may be assumed, i.e. the lower part of the side projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area $A_1$.
Deck cargo as given by the nominal capacity condition (as defined in 3.6.2.10 of this Chapter) is to be included for the determination of side-projected area $A_1$. The summer load waterline may be used for the calculation of condition with deck cargo. Deck cargo may not need to be considered if a ballast draft condition generates a larger side-projected area $A_1$ than the full load condition with cargo on deck. The larger of both side-projected areas is to be chosen as side-projected area $A_1$.
(1) The mooring lines as given here under are based on a maximum current speed of 1.0 m/s and the following maximum wind speed, in m/s:

$V_W$ $= 25 - 0.002(A_1 - 2000)$ for passenger ships, ferries, and car carriers with 2000 m$^2$ < $A_1$ ≤ 4000 m$^2$

$= 21$ for passenger ships, ferries, and car carriers with $A_1$ > 4000 m$^2$

$= 25$ for other ships

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current. Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it is to be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.
Breast line: A mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.
Spring line: A mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.
Head/Stern line: A mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

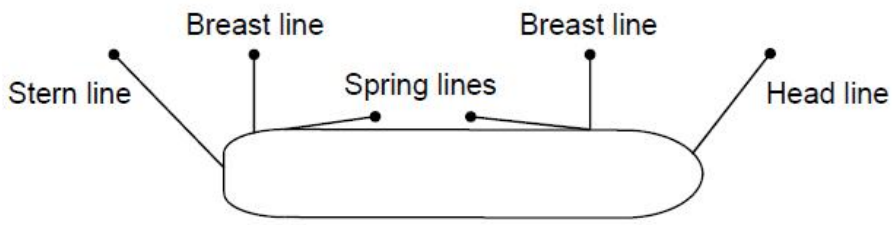



**Figure 3.2.4.2 Breast line, spring line, head/stern line**

(2) The ship design minimum breaking strength, in kN, of the mooring lines for ships with EN>2000 is not to be less than the value obtained from the following formula and to be limited to 1275 kN:

$$MBL_{SD} = 0.1 \cdot A_1 + 350 \quad \text{kN}$$

However, in this case the mooring lines are to be considered as not sufficient for the wind speed given in (1), the acceptable wind speed $V_W^*$, in m/s, can be estimated as follows:

$$V_W^* = V_W \sqrt{\frac{MBL_{SD}^*}{MBL_{SD}}}$$

where: $V_w$ is the wind speed as per (1);

$MBL_{SD}^*$ is the ship design breaking strength of the mooring lines intended to be supplied, to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL_{SD}^* \geq \left(\frac{21}{V_W}\right)^2 \cdot MBL_{SD}$$

$MBL_{SD}$ — the ship design breaking strength as recommended according to the formula in (2).

If lines are intended to be supplied for an acceptable wind speed $V_W^*$ higher than $V_W$ as per (1), the ship design minimum breaking strength is to be taken as:

$$MBL^{*}_{SD} = \left(\frac{V^{*}_{W}}{V_{W}}\right)^{2} \cdot MBL_{SD}$$

(3) The total number of head, stern and breast lines for ships with EN>2000 is not to be less than:

$$n = 8.3 \cdot 10^{-4} \cdot A_1 + 6$$

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern and breast lines is to be taken as:

$$n = 8.3 \cdot 10^{-4} \cdot A_1 + 4$$

The total number of head, stern and breast lines is to be rounded to the nearest whole number.

(4) The number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted strength, $MBL^{**}_{SD}$, is to be taken as:

$$MBL^{**}_{SD} = 1.2 \cdot MBL_{SD} \cdot n / n^{**} \le MBL_{SD} \qquad \text{for increased number of lines,}$$

$$MBL^{**}_{SD} = MBL_{SD} \cdot n / n^{**} \qquad \text{for reduced number of lines.}$$

where: $MBL_{SD}$ is $MBL_{SD}$ or $MBL^{*}_{SD}$ specified in (1) and (2) of this paragraph;

$n^{**}$ is the increased or decreased total number of head, stern and breast lines;

$n$ the number of lines for the considered ship type as calculated by the above formulas without rounding.

(5) The total number of spring lines is to be taken not less than:

Two lines where EN < 5000,

Four lines where EN $\geqslant$ 5000.

The ship design minimum breaking strength of spring lines is to be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking strength of the lines, the number of spring lines is to be increased in accordance with the following formula, but rounded up to the nearest even number.

$$n^{*}_{S} = MBL_{SD} / MBL^{**}_{SD} \cdot n_S$$

where: $MBL_{SD}$ is $MBL_{SD}$ or $MBL^{*}_{SD}$ specified in (1) and (2) of this paragraph;

$n_S$ is the number of spring lines;

$n^{*}_{S}$ is the increased number of spring lines.

3.2.4.4 The length of mooring lines for ships with EN of less than or equal to 2000 may be taken from Table 3.2.1.1(2). For ships with EN > 2000 the length of mooring lines may be taken as 200 m. The lengths of individual mooring lines may be reduced by up to 7% of the above given lengths, but the total length of mooring lines is not to be less than would have resulted had all lines been of equal length.

3.2.4.5 The wire ropes for towlines listed in Table 3.2.1.1(2) of this Section are to be of a flexible, galvanized construction having a breaking strength of not less than 1.37 kN/mm$^2$ per wire. The construction type of the wire ropes is to be referred to the provisions in Section 4, Chapter 10, PART ONE of CCS Rules for Materials and Welding.

3.2.4.6 Towlines and mooring lines may be of natural fibre, synthetic fibre material or a mixture of wire and natural fibre. In no case is the circumference of the ropes made of natural fibre or synthetic fibre to be less than 63 mm (20 mm in diameter).

3.2.4.7 All ropes having a breaking strength in excess of 736 kN are to be handled by specially designed winches.

3.2.4.8 In engineering ships, service winches may be used in lieu of windlasses, provided that these winches can efficiently handle chain cables.

### 3.2.5 Strength requirements for securing of windlasses on fore decks

3.2.5.1 Paragraph 3.2.5 of this Section provides strength requirements for the securing of windlasses located on the exposed deck over the forward 0.25*L* of all ships of 80 m or over in length, where the height of the exposed deck in way of the windlasses is less than 0.1*L* or 22 m above the summer load waterline, whichever is the lesser.

3.2.5.2 Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

3.2.5.3 The following pressures and associated areas are to be applied (see Figure 3.2.5.3):

(1) Force $P_x$ = 200 kN/m$^2$ normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction.
(2) Force $P_y$ = 150 kN/m$^2$ parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of $f$ times the projected area in this direction, where $f$ is defined as:

$$f = 1 + \frac{B}{H}, \text{ but not greater than 2.5}$$

where: $B$ — width of windlass measured parallel to the shaft axis, in m;
$H$ — overall height of windlass, in m.

3.2.5.4 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by $N$ bolt groups, each containing one or more bolts, see Figure 3.2.5.3.

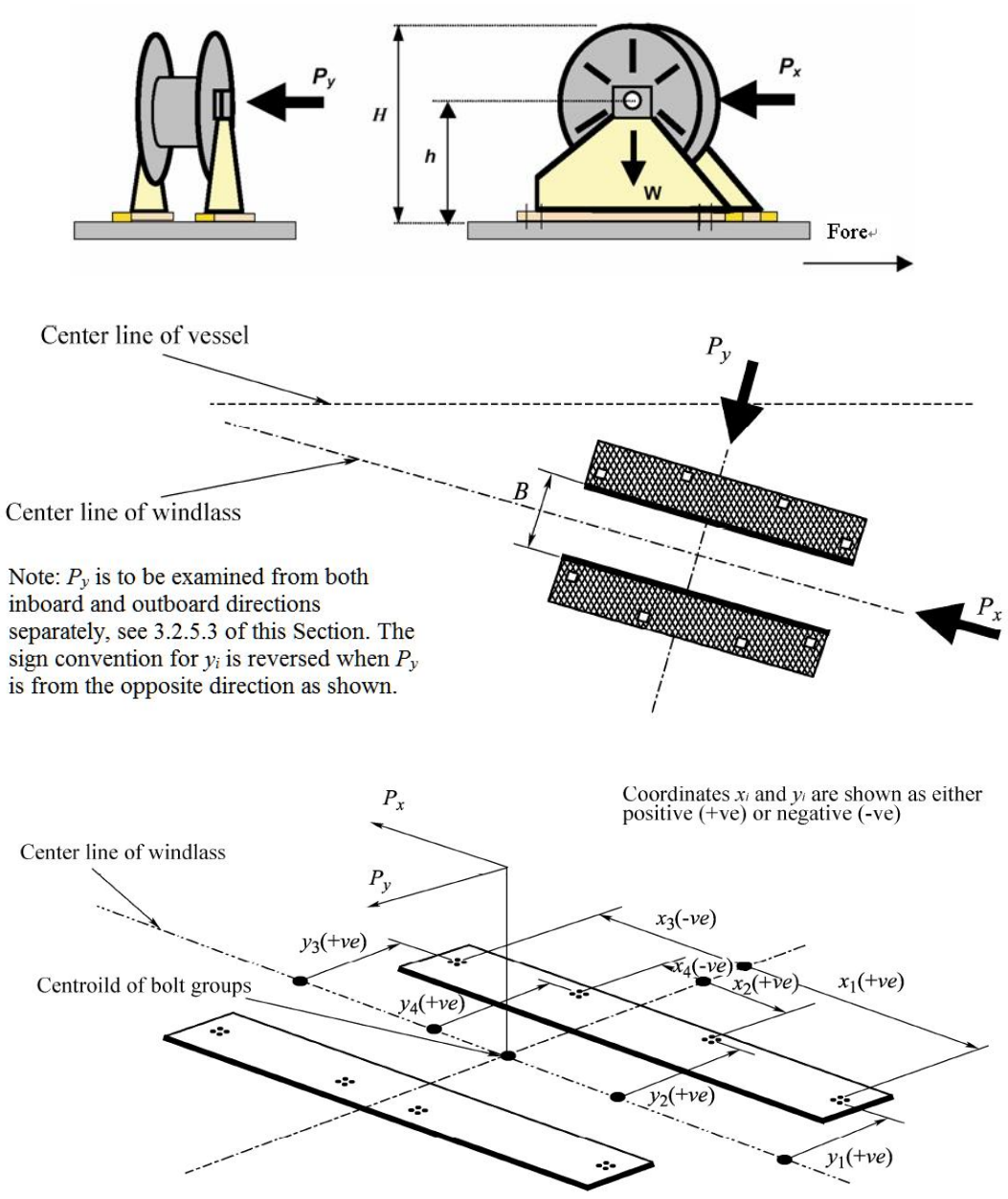



**Figure 3.2.5.3**

3.2.5.5 The axial force $R_i$ in bolt group (or bolt) $i$, may be calculated from:

$$R_{xi} = \frac{P_x h x_i A_i}{I_x} \quad \text{kN}$$

$$R_{yi} = \frac{P_y h y_i A_i}{I_y} \quad \text{kN}$$

$$R_i = R_{xi} + R_{yi} - R_{si} \quad \text{kN}$$

where: $P_x$ — force acting normal to the shaft axis, in kN;

$P_y$ — force acting parallel to the shaft axis, in kN, either inboard or outboard, whichever gives the greater force in bolt group $i$;

$h$ — shaft height above the windlass mounting, in cm;

$x_i$, $y_i$ — $x$ and $y$ coordinates of bolt group $i$ from the centroid of all $N$ bolt groups, positive in the direction opposite to that of the applied force, in cm;

$A_i$ — cross sectional area of all bolts in group $i$, in cm$^2$;

$I_x = \sum A_i x_i^2$, in cm$^4$, sum of moments of inertia for $N$ bolt groups about $y$-axis;

$I_y = \sum A_i y_i^2$, in cm$^4$, sum of moments of inertia for $N$ bolt groups about $x$-axis;

$R_{si}$ — static reaction at bolt group $i$, due to weight of windlass, in kN.

3.2.5.6 Shear forces $F_{xi}$, $F_{yi}$ applied to the bolt group $i$, and the resultant combined force $F_i$ may be calculated from:

$$F_{xi} = \frac{P_x - agW}{N} \quad \text{kN}$$

$$F_{yi} = \frac{P_y - agW}{N} \quad \text{kN}$$

$$F_i = \sqrt{F_{xi}^{\ 2} + F_{yi}^{\ 2}} \quad \text{kN}$$

where: $\alpha$ — coefficient of friction, taken as 0.5;

$W$ — mass of windlass, in t;

$g$ — gravity acceleration, taken as 9.81m/s$^2$;

$N$ — number of bolt groups.

3.2.5.7 Axial tensile and compressive forces in 3.2.5.5 of this Section and lateral forces in 3.2.5.6 of this Section are to be considered in the design of the supporting structure.

3.2.5.8 Tensile axial stresses in the individual bolts in each bolt group are to be calculated. The horizontal forces $F_{xi}$ and $F_{yi}$ are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. The safety factor against bolt proof strength is not to be less than 2.0. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.2.5.9 Direct calculation is to be performed for the strength of the deck framing supporting the windlass and its securing bolt loads as defined in 3.2.5.3 to 3.2.5.7 of this Section.

# Section 3 CEILINGS AND CARGO BATTENS

### 3.3.1 Ceiling

3.3.1.1 Wood ceiling is to be laid from the floors to the upper part of the bilge in single bottom ships, and over the bilges in ships having double bottoms. The ceiling is to be arranged so as to be readily removable for inspection.

3.3.1.2 Where ceiling is to be laid on the inner bottom under hatchways, battens are to be laid underneath the ceiling, and the thickness of the battens is to be at least 30 mm. Where the double bottom tank is not intended to carry oil fuel, ceiling may be laid directly on the inner bottom plating embedded in a suitable bituminous solution or other effective coverings.

3.3.1.3 Either in single or double bottom ships, the thickness of the ceiling in cargo holds is to be determined according to the ship's length $L$ as follows:

for $L \leq 60$ m, not less than 50 mm;

for 60 m $< L \leq 90$ m, not less than 55 mm;

for $L > 90$ m, not less than 60 mm.

3.3.1.4 Bottom ceiling or shaft tunnel ceiling under hatchways may be omitted provided that the thickness of the inner bottom plating or shaft tunnel top plating is increased by 2 mm.

3.3.1.5 If cargo is handled by grabs or similar mechanical appliances, double layers of ceiling are to be fitted on the inner bottom under hatchways (the thickness of each ceiling layer is to be in compliance with 3.3.1.3 of this Section); if the thickness of the inner bottom plating is increased by 5 mm, the wood ceiling may be omitted.

3.3.1.6 If cargo is carried in a hold adjacent to a deep oil tank with heating appliances, the hold side of the bulkhead is to be fitted with wood ceiling or insulation. If wood ceiling is fitted, the thickness is to comply with the requirements of 3.3.1.3 of this Section.
3.3.1.7 The covers or fittings of the manholes in cargo holds are, so far as practicable, not to project above the inner bottom plating or bottom ceiling; but if impracticable, they are to be protected by a steel coaming around each manhole, and such coamings together with wood ceiling or steel covers thereon are to be gradually sloped down to the flush surface of the inner bottom plating or bottom ceiling.
3.3.1.8 The external surface of tank top plating or shaft tunnel top plating covered by wood ceiling is to be coated with bituminous solution or other effective coating. Tank top plating and shaft tunnel top plating not covered by wood ceiling are to be coated with paints.

### 3.3.2 Cargo battens

3.3.2.1 Wood cargo battens are to be fitted at ship sides in cargo holds intended for the carriage of general cargoes. The clear space between adjacent rows of the cargo battens is not to exceed 300 mm, and the thickness and breadth of the cargo battens are to be determined in relation to the ship's length $L$ as follows:

for $L \leq 60$ m, breadth not less than 100 mm, and thickness not less than 30 mm;

for 60 m $< L \leq$ 90m, breadth not less than 120 mm, and thickness not less than 40 mm;

for $L > 90$ m, breadth not less than 150 mm, and thickness not less than 50 mm.

Cargo battens may be made of steel.

## Section 4 MASTS OR DERRICK POSTS

### 3.4.1 General requirements

3.4.1.1 Masts or derrick posts intended to support light derricks are to have at least two points of effective support. The superstructure deck with sufficient strength or the top of a substantial house may be used as one of the points of effective support.
3.4.1.2 Masts or derrick posts are to be effectively attached to the deck plating (at the point of support) where they pass through the deck, and the openings in the deck plating are to be effectively strengthened and compensated.

### 3.4.2 Wall thickness

3.4.2.1 The relative values between the outside diameter $D$ and wall thickness $t$ of the masts or derrick posts are to be in compliance with those given in the following formulae:

$$D \leq \frac{1000t}{25-t} \quad \text{mm for } t \leq 15 \text{ mm}$$

$$D \leq 100t \quad \text{mm for } t > 15 \text{ mm}$$

3.4.2.2 The minimum wall thickness of masts or derrick posts is to be 6 mm; if the masts or derrick posts are used as ventilator pipes, the minimum wall thickness is not to be less than 7 mm.

### 3.4.3 Local strengthening

3.4.3.1 Masts or derrick posts intended to support light derricks are to be increased in thickness or doubled in plating, as appropriate, in way of the lower end, crosstrees, derrick seatings, and fixed eye plates for topping lifts or stays where concentrated loads may be expected to occur. Where strengthening is made by doubling plates, the depth and breadth of the doubling plates are to be slightly greater than those of the above fittings or the outside diameter of the masts or derrick posts in way, as appropriate.
3.4.3.2 The conditions and the factor of safety for strength calculations of masts or derrick posts are to comply with the requirements of the flag State Administration.

## Section 5 EMERGENCY TOWING ARRANGEMENTS

### 3.5.1 Application

3.5.1.1 This Section applies to liquid cargo carriers of 20,000 tons deadweight and over, including oil tankers, chemical tankers and liquefied gas carriers, for being towed out of dangerous areas in emergency cases with the arrangements needed.

3.5.2.1 The following plans and documents are to be submitted for approval:

(1) Details of emergency towing arrangements;
(2) Details of strongpoints and fairleads of emergency towing arrangements (related calculations are also to be submitted for information);
(3) Local structures supporting strongpoints and fairleads;
(4) Operation manual for emergency towing arrangements.

### 3.5.3 General requirements

3.5.3.1 The emergency towing arrangements are to be so designed that they are capable of easy operation and rapid connection to the towing vessel in the absence of main power of the ship.

3.5.3.2 The emergency towing arrangements are to be subject to approval and in accordance with the following requirements:

(1) The aft emergency towing arrangement is to be pre-rigged and capable of being deployed in harbour conditions in not more than 15 min.

(2) The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions. The pick-up gear is to be protected against the weather and other adverse conditions.

(3) The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

(4) The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 h.

(5) Forward emergency towing arrangements that comply with the requirements for aft emergency towing arrangements may be accepted.

(6) All emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

### 3.5.4 Arrangement and strength

3.5.4.1 typical details of emergency towing arrangements, see Figure 3.5.4.1.

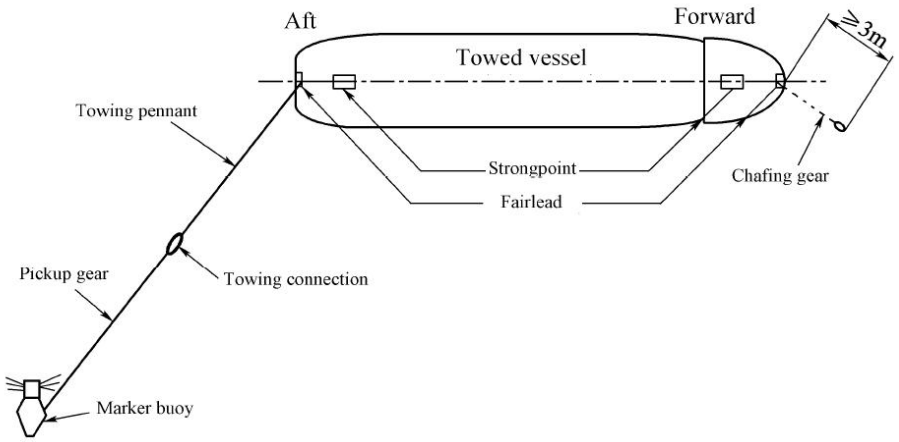



**Figure 3.5.4.1 Typical Details of Emergency Towing Arrangements**

The bow and stern strongpoint and fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimize the stress on the towing system. Main components of towing arrangements are as shown in Table 3.5.4.1.

**Major Components of Towing Arrangements** **Table 3.5.4.1**

| Major components | Location | | Strength requirements |
|---|---|---|---|
| | Forward of ship | Aft of ship | |
| Pick-up gear | Optional | Yes | – |
| Towing pennant | Optional | Yes | Yes |
| Chafing gear | Yes | Depending on design | Yes |
| Fairlead | Yes | Yes | Yes |
| Strongpoint | Yes | Yes | Yes |
| Roller pedestal | Yes | Depending on design | – |

3.5.4.2 The strength of towing arrangements is to be sufficient for all relevant angles of towline during towing operations, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards. The safety factor of main components of towing arrangements is not to be less than 2. For safe working loads (SWL) of main components of towing arrangements, see Table 3.5.5.2.

**Safe Working Load of Components** **Table 3.5.4.2**

| Deadweight of ship (t) | Safe working load (kN) |
|---|---|
| 20000 to 50000 | 1000 |
| ≥ 50000 | 2000 |

### 3.5.5 Requirements for the arrangements and components

3.5.5.1 The towing pennant is to have a hard eye-formed termination allowing connection to a standard bow shackle. The towing pennant is to have a length of at least $2H + 50$ m ($H$ being the lightest seagoing ballast freeboard height at the fairlead, in m).

3.5.5.2 Different solutions on design of chafing gear may be used. If a chafing chain is used, the following requirements are to be complied with:

(1) the chafing chain is to be stud link chain and is to extend from the strongpoint to a point at least 3 m beyond the fairlead;

(2) one end of the chafing chain is to be suitable for connection to the strongpoint. The other end is to be fitted with a standard pear-shaped open link allowing connection to the towing pennant via a standard bow shackle. A typical outboard chafing chain end and a pear-shaped open link are shown in Figure 3.5.5.2(2);

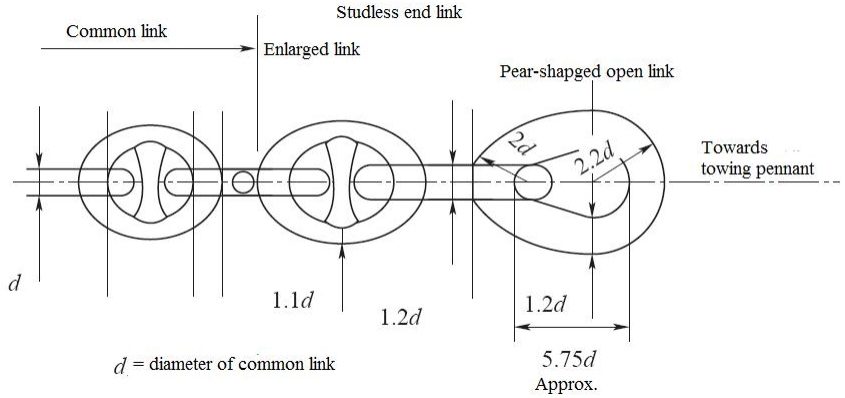



**Figure 3.5.5.2(2) Typical Outboard Chafing Chain End**

(3) in addition to this Section, the chafing chain is to be designed, manufactured, tested and certified in accordance with the relevant requirements of Section 2, Chapter 10 of PART ONE of CCS Rules for Materials and Welding;

(4) chafing chains are to be made of M2 or M3 chain steel by manufacturers as approved;

(5) the nominal diameter of common links for chafing chains is to comply with the values indicated in Table 3.5.5.2(5) and the nominal diameter of other links are to be determined according to Figure 3.5.5.2(2);

(6) the chafing chain is to be stowed in such a way that it can be rapidly connected to the strongpoint.

**Minimum Nominal Diameter of Common Link** **Table 3.5.5.2(5)**

| Type of emergency towing arrangement (ETA) | Minimum nominal diameter of common link $d$ | |
|---|---|---|
| | Grade 2 | Grade 3 |
| ETA1000 | 62 mm | 52 mm |
| ETA2000 | 90 mm | 76 mm |

3.5.5.3 The fairleads may be mooring fairleads or fairleads with cable rollers. Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant and associated components. The recommended size of such openings is 450 mm × 600 mm. The fairlead is to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead. The fairlead is to have an adequate bearing surface, and the bending ratio (towing pennant bearing surface diameter to towing pennant diameter) is not to be less than 7:1.

3.5.5.4 The strongpoint is the inboard end fastening of the towing arrangement and is to be a stopper or bracket or other fitting of equivalent strength. The strongpoint may be designed integral with the fairlead.

# Section 6 SHIPBOARD FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING ON CONVENTIONAL VESSELS

### 3.6.1 General requirements

3.6.1.1 This Section applies to design and construction of shipboard fittings and supporting structures used for the normal towing and mooring operations.

3.6.1.2 The minimum net scantlings of the supporting hull structure are to comply with the requirements given in 3.6.3.5 and 3.6.4.5 of this Section. The net thicknesses, $t_{net}$, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, $t_c$, given in 3.6.6 of this Section, to $t_{net}$.

3.6.1.3 This Section applies to ships the contract of which is placed on or after 1 July 2018.

3.6.1.4 This Section is not applicable to escort towing, canal transit towing and emergency towing for tankers.

### 3.6.2 Definitions

3.6.2.1 Conventional vessels mean new displacement-type vessels of 500 GT and above, excluding high speed craft, special purpose vessels, and offshore units of all types. Special purpose ship means a mechanically self-propelled ship which by reason of its function carries on board more than 12 special personnel.

3.6.2.2 Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the normal mooring of the vessel and the similar components used for the normal towing or other towing of the vessel. Other components such as capstans, winches, etc. are not covered by this Section. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an industry standard subject to that standard.

3.6.2.3 Supporting hull structures mean that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for the normal towing or other towing and mooring operations mentioned above is also subject to this Section.

3.6.2.4 Industry standard means international standard (ISO, etc.) or standards issued by national association which are recognized in the country where the ship is built.

3.6.2.5 Normal towing means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.

3.6.2.6 Other towing means for ships, not subject to Section 5 of this Chapter, but intended to be fitted with equipment for towing by another ship or a tug, e.g. such as to assist the ship in case of emergency.

3.6.2.7 Escort towing means towing service, in particular, for laden oil tankers or LNG carriers, required in specific estuaries. Its main purpose is to control the ship in case of failures of the propulsion or steering system.

3.6.2.8 Canal transit towing means towing service for ships transiting canals.

3.6.2.9 Emergency towing for tankers means towing service to assist tankers in case of emergency, see Section 5 of this Chapter.

3.6.2.10 The nominal capacity condition is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For container ships the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

3.6.2.11 Ship Design Minimum Breaking Load (MBLSD) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.

3.6.2.12 Line Design Break Force (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

### 3.6.3 Towing

3.6.3.1 The strength of shipboard fittings used for normal towing or other towing operations at bow, sides and stern and their supporting hull structures are to comply with the requirements of 3.6.3.2 to 3.6.3.6 of this Section. For fittings intended to be used for, both, towing and mooring, 3.6.4 applies to mooring.

3.6.3.2 Shipboard fittings for towing are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

3.6.3.3 Load considerations

The minimum design load applied to supporting hull structures for shipboard fittings is to be:

(1) For normal towing operations, 1.25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan.

(2) For other towing service, the ship design minimum breaking load of the towline corresponding to equipment no. *N* in Table 3.2.1.1(2) is to be applied.

Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of towing lines and the breaking loads of towing lines are used as the design loads.

(3) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to (1) and (2).

(4) When a safe towing load TOW greater than that determined according to 3.6.3.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate TOW/design load relationship.

(5) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, however, the load need not be more than twice the design load.

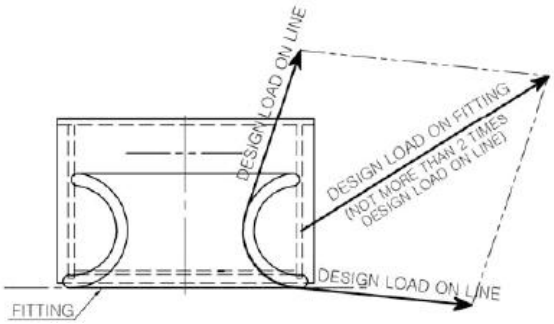



**Figure 3.6.3.3(5)**

3.6.3.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the following loads.

(1) For normal towing operations, the intended towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan,

(2) For other towing service, the ship design minimum breaking load of the tow line according to Table 3.2.1.1(2) (see Notes in 3.6.3.3(2)),

(3) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to (1) and (2).

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.3.3 and 3.6.3.5. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be included as defined in 3.6.7. At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

3.6.3.5 Supporting hull structure

(1) Arrangement:

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) below for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

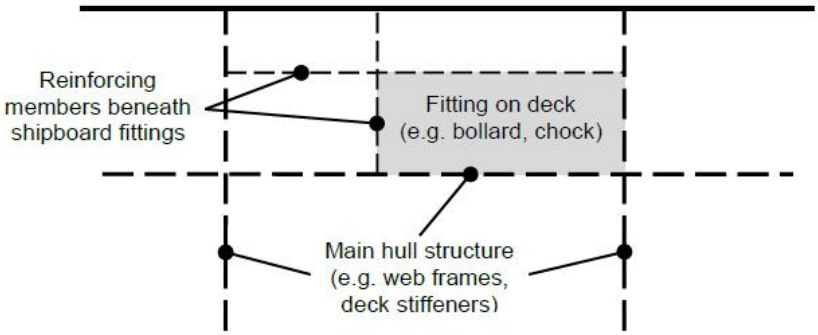



Figure 3.6.3.5(1)

(2) Acting point of towing force:
The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a towing line or at a change in its direction. For bollards and bitts the attachment point of the towing line is to be taken not less than 4/5 of the tube height above the base, see Figure 3.6.3.5(2).

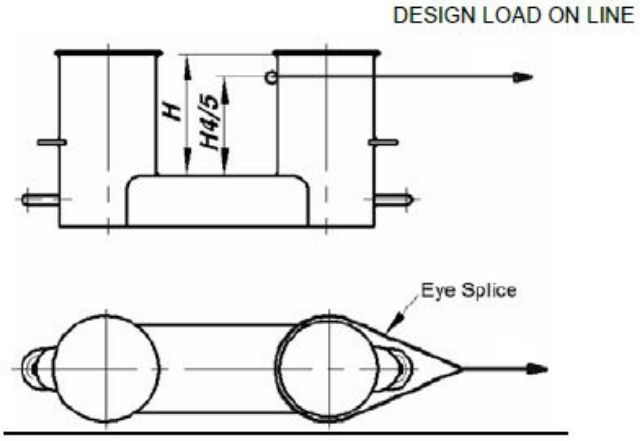



Figure 3.6.3.5(2)

(3) Allowable stresses:
Allowable stresses under the design load conditions as specified in 3.6.3.3 of this Section are as follows:
1) For strength assessment with beam theory or grillage analysis:
Normal stress: $1.0R_{eH}$ ;
Shearing stress: $0.6R_{eH}$ ;
Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.
(2) For strength assessment with finite element analysis:
Von Mises stress: $1.0R_{eH}$ .
For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.
$R_{eH}$ is the specified minimum yield stress of the material.

3.6.3.6 Safe Towing Load (TOW)
(1) The safe towing load (TOW) is the safe load limit of shipboard fittings used for towing purpose.
(2) TOW used for normal towing operations is not to exceed 80% of the design load per 3.6.3.3 (1).

(3) TOW used for other towing operations is not to exceed 80% of the design load according to 3.6.3.3 (2).
(4) For fittings used for both normal and other towing operations, the greater of the safe towing loads according to (2) and (3) is to be used.
(5) TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing. For fittings intended to be used for, both, towing and mooring, SWL, in t, according to 3.6.4.6 is to be marked in addition to TOW.
(6) The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.
(7) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of towing lines.

### 3.6.4 Mooring

3.6.4.1 The strength of shipboard fittings used for mooring operations and of their supporting hull structures as well as the strength of supporting hull structures of winches and capstans is to comply with the requirements of 3.6.4.2 to 3.6.4.6 of this Section.
3.6.4.2 Shipboard fittings, winches and capstans for mooring are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the service. For fittings intended to be used for, both, mooring and towing, 3.6.3 applies to towing.
3.6.4.3 Load considerations
(1) The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter.
Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for assessment of transverse wind load, tug arrangement and selection of mooring lines.
(2) The minimum design load applied to supporting hull structures for winches is to be 1.25 times the intended maximum brake holding load, where the maximum brake holding load is to be assumed not less than 80% of the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter. For supporting hull structures of capstans, 1.25 times the maximum hauling-in force is to be taken as design load.
(3) When a safe working load SWL greater than that determined according to 3.6.4.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate SWL/design load relationship.
(4) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the mooring line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, refer to Figure 3.6.3.3(5). However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.
3.6.4.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the ship design minimum breaking strength according to 3.2.4 of this Chapter.
Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.
When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.4.3 and 3.6.4.5 of this Section. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion. It is to be observed that in this case either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be included as defined in 3.6.7. At the discretion of the classification society, load tests may be accepted as alternative to strength assessment by calculations.
3.6.4.5 Supporting hull structure
(1) Arrangement:
Arrangement of the reinforced members beneath shipboard fittings is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.
(2) Acting point of mooring force:
The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line

is to be taken not less than 4/5 of the tube height above the base, see a) in Figure 3.6.4.5(2) a). If fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see Figure 3.6.4.5(2) b).

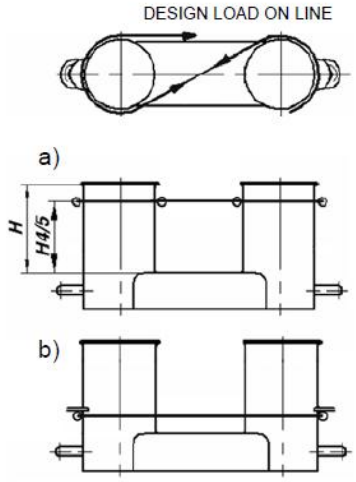



**Figure 3.6.4.5(2)**

(3) Allowable stresses:
Allowable stresses under the design load conditions as specified in 3.6.4.3 of this Section are as follows:
1) For strength assessment with beam theory or grillage analysis:
Normal stress: $1.0R_{eH}$ ;
Shearing stress: $0.6R_{eH}$ ;
Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.
2) For strength assessment with finite element analysis:
Von Mises stress: $1.0R_{eH}$ .
For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.
3.6.4.6 Safe Working Load (SWL)
(1) The Safe Working Load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.
(2) Unless a greater SWL is requested by the applicant according to 3.6.4.3(3), the SWL is not to exceed the ship design minimum breaking strength according to 3.2.4 of this Chapter.
(3) The SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. For fittings intended to be used for, both, mooring and towing, TOW, in t, according to 3.6.3.6 is to be marked in addition to SWL.
(4) The above requirements on SWL apply for the use with no more than one mooring line.
(5) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of mooring lines.

### 3.6.5 Towing and mooring arrangements plan

(1) The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.
(2) Information provided on the plan is to include in respect of each shipboard fitting:

1) location on the ship;
2) fitting type;
3) SWL/TOW;
4) purpose (mooring/harbour towing/other towing); and
5) manner of applying towing or mooring line load including limiting fleet angles.

The purposes and method for applying loads are to be taken into account in the determination of SWL and TOW of fittings and submitted for approval.

Furthermore, information provided on the plan is to include:

1) the arrangement of mooring lines showing number of lines (N);
2) the ship design minimum breaking load ($MBL_{SD}$);
3) the acceptable environmental conditions for ship design minimum breaking load for ships with Equipment Number EN > 2000, including 30 second mean wind speed from any direction and maximum current speed acting on bow or stern (±10°).

(3) The information as given in (2) is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/other towing operations.

### 3.6.6 Corrosion addition

The total corrosion addition, $t_c$, in mm, is not to be less than the following values:

(1) For the supporting hull structure, 2 mm;

(2) For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard, 2.0 mm.

(3) For shipboard fittings not selected from an accepted industry standard, 2.0 mm.

### 3.6.7 Wear allowance

In addition to the corrosion addition given in 3.6.6 the wear allowance, tw, for shipboard fittings not selected from an accepted industry standard is not to be less than 1.0 mm, added to surfaces which are intended to regularly contact the line.

### 3.6.8 Survey after construction

The condition of deck fittings, their pedestals or foundations, if any, and the hull structures in the vicinity of the fittings are to be examined in accordance with the Rules.

## Section 7 SUPPORT STRUCTURE FOR DECK EQUIPMENT

### 3.7.1 General requirements

3.7.1.1 Information pertaining to the support structure of deck equipment and fittings, as listed in 3.7.1.2(1) to (5) of this Section, is to be submitted for approval. Support structure means that part of the ship structure on/in which deck equipment and fittings are placed and which is directly subjected to the forces acting on the deck equipment and fittings.

3.7.1.2 This Section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:

(1) anchor windlasses;

(2) anchoring chain stoppers;

(3) deck cranes, derricks and lifting masts;

(4) emergency towing arrangements;

(5) other deck equipment and fittings which are subject to specific approval.

3.7.1.3 Where deck equipment is subject to multiple load cases, such as an operational load and a green seas load, the operational load and green seas load are be applied independently for the evaluation of strength of foundations and support structure.

### 3.7.2 Supporting structures for anchoring windlass and chain stopper

3.7.2.1 The following plans and information are to be submitted for approval:

(1) Details of the supporting structure for the anchor windlass;

(2) Details of the windlass foundation design, including material specifications for holding down bolts and the connection of the foundation to the deck;

(3) Details of the chain stopper foundation design, including material specification and the connection of the foundation to the deck.

3.7.2.2 The following plans and information are also to be submitted:

(1) General arrangement drawing of anchoring equipment;
(2) Design loads as specified in 3.7.2.3 and 3.7.2.4 of this Section and associated reaction forces applied to the foundation and supporting structure.

3.7.2.3 The following load cases are to be examined for the strength of supporting structures of windlasses and chain stoppers:
(1) windlass where chain stopper is provided: 45% of breaking load;
(2) windlass where chain stopper is not provided: 80% of breaking load;
(3) chain stopper: 80% of breaking load.
The breaking load is the minimum breaking load of chain as defined according to Table 3.2.1.1(2) of this Chapter. The loads are to be applied in the direction of chain.

3.7.2.4 For windlasses complying with the requirements of 3.2.5.1 of this Chapter, the strength of securing of windlasses on fore deck is also to be checked in accordance with the requirements of 3.2.5 of this Chapter.

3.7.2.5 When checking the strength of supporting structures and foundations, a three-dimensional finite element model is to be applied as far as possible in the analysis to more exactly describe the distribution of structural response in all directions. Where a beam system is or plate girders are used, the model is to be reasonably simplified and be more conservative. The analysis is to be based on the theory of linear elasticity. The thicknesses of structural members in the model are net ones. Corrosion allowance is in accordance with 1.6.5, Section 6, Chapter 1 of this PART.

3.7.2.6 The principles for extent, element types and boundary conditions of a three-dimensional model are as follows:
(1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle ($a \times b$) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle ($3a \times 3b$). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least $D/4$ ($D$ being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.
(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in 1.5.6, Section 5, Chapter 1 of this PART.

(1) 3.7.2.7 For all loading conditions, the stresses taken in calculation for supporting structures and foundations are not to exceed the following permissible values:For strength assessment by means of beam theory or grillage analysis:
Normal stress: 1.0 $R_{eH}$
Shear stress: 0.6 $R_{eH}$
The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.
(2) For strength assessment by means of finite element analysis:
Von Mises stress: 1.0 $R_{eH}$
For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.
$R_{eH}$ is the specified minimum yield stress of the material.

### 3.7.3 Supporting structure for cranes, derricks and lifting masts

3.7.3.1 The supporting structures of lifting appliances which are identified as basic features of the ship, such as lifting appliances of floating crane and submersible handling system of submersible supply vessel

are to comply with the requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.
The supporting structures of other lifting appliances, including cranes, derricks and lifting masts with a safe working load greater than 30 kN, or a maximum overturning moment to the supporting structure greater than 100 kN·m, are to comply with the requirements of this Section.
3.7.3.2 These requirements do not cover the following items:
(1) supports of lifting appliances for personnel or passengers, see 3.7.5.2 of this Section;
(2) the structure of the lifting appliance pedestals or post above the area of the deck connection;
(3) holding down bolts and their arrangement, which are considered part of the lifting appliance.
3.7.3.3 The term lifting appliance is defined as a crane, derrick or lifting mast.
3.7.3.4 The safe working load is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.
3.7.3.5 The self-weight is the calculated gross self-weight of the lifting appliance, including the weight of any lifting gear.
3.7.3.6 The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at safe working load, taking into account outreach and self-weight.
3.7.3.7 The following plans and information are to be submitted for approval:
(1) Details of the supporting structure of the lifting appliance, including its connection of the deck;
(2) Details of the safe working load, self-weight, vertical reaction forces and the maximum overturning moment in the supporting structure of the lifting appliance;
(3) For offshore operation, the maximum sea state in which the lifting appliance is to be used.
3.7.3.8 The general arrangement drawing of the crane/derrick/lifting mast is also to be submitted.
3.7.3.9 For lifting appliances which are limited to use in harbour, the load cases to be examined are to include 130% of the safe working load added to the lifting appliances self-weight.
3.7.3.10 For lifting appliances which may be used for offshore (refers to open waters, the sea condition of which will cause significant motion of the ship, and the wind force at sea normally exceeds Beaufort scale 2) operations, the following are to be submitted for approval:
(1) The maximum sea state in which the lifting appliance is to be used;
(2) The worst case vertical and horizontal accelerations;
(3) The worst case wind loadings for the specified design sea state and wind environment.
(4) The load scenario to be examined is to account for these environmental loads. As a minimum, the 150% of the safe working load added to the lifting appliances self-weight is to be examined.
3.7.3.11 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.
3.7.3.12 In all conditions, the stresses taken in calculation for the supporting structures and foundations of lifting appliances are not to exceed the permissible values given in Table 3.7.3.12.

**Permissible Stress** **Table 3.7.3.12**

| Type of element | Permissible stress |
|---|---|
| Grillage | Direct stress: $[\sigma]=0.67R_{eH}$<br>Shear stress: $[\tau]=0.39R_{eH}$ |
| Plate element | Equivalent stress: $[\sigma_c]=0.80R_{eH}$ |

where: $R_{eH}$ – yield stress of material, in N/mm$^2$.

3.7.3.13 In addition to the requirement of 3.7.3.12 of this Section, the capability of the supporting structure to resist buckling failure is to be checked according to the requirements of 1.5.9, Section 5, Chapter 1 of this PART. In buckling strength assessment, the standard thickness deduction of structural members is to be taken as 1.0 mm and the minimum buckling safety factor taken as 1.0.

### 3.7.4 Supporting structures for components used in emergency towing arrangements

3.7.4.1 Tankers (including oil tankers, chemical tankers and liquefied gas carriers) carrying flammable liquid cargoes in bulk, having a deadweight of not less than 20,000 tonnes are to be fitted with an emergency towing arrangement at both fore and aft ends.
3.7.4.2 The safe working load of emergency towing arrangements is as follows:
(1) 1,000 kN for vessels having a deadweight greater than or equal to 20,000 tonnes, but less than 50,000 tonnes;
(2) 2,000 kN for vessels having a deadweight greater than or equal to 50,000 tonnes.
3.7.4.3 The following plans are to be submitted for approval:

Details of the supporting structure for the emergency towing arrangement, including the connection to the deck.

3.7.4.4 The following supporting information is also to be submitted:

Details of the emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.7.4.5 The deck in way of strongpoints and fairleads is to have a minimum gross thickness of 15 mm.

3.7.4.6 The design load for the connection of the strongpoint and fittings to the deck and its supporting structure is to be taken as twice the safe working load. The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed.

3.7.4.7 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.

3.7.4.8 For the design load specified in 3.7.4.6 of this Section, the stresses induced in the supporting structure and welds, in way of strongpoints and fairleads, are not to exceed the permissible values given in 3.7.2.7 of this Section.

3.7.4.9 The capability of the structure to resist buckling failure is also to be assured.

### 3.7.5 Supporting structures for other deck equipment or fittings which are subject to specific approval

3.7.5.1 The following requirements relate to other items of deck equipment which are not covered by 3.7.2 to 3.7.4 of this Section. The following details are to be submitted for approval. They may be indicated separately or may be included on the main structural drawings:

(1) Plans showing the supporting structure for deck equipment/fittings;

(2) Details of the loads imposed on the structure by the deck equipment/fittings.

3.7.5.2 Support for lifting appliances for personnel is to be provided as follows:

(1) in general, lifesaving appliances (lifeboats, life rafts and rescue boats) are to be stowed on a purpose built cradle, seat or deployment appliance. The design load imposed on the ship structure is to be established by the supplier of the lifesaving appliance (to include 2.2 times of bearing reaction and torque under maximum working load as a minimum). For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones. The calculated stresses are not to exceed the permissible values given in Table 3.7.3.12. The supplier of the life-saving appliance is to provide corresponding calculation information;

(2) the support structure is to be adequate for the design loads. Local stiffening and a local increase in plating thickness is to be provided. Primary supporting members may be required. Additional national and international Regulations are to be applied, where applicable;

(3) support structure for crew lifts is to be provided in way of the anchor points of lift operating equipment;

(4) support structure for boarding (accommodation) ladders is to be provided in way of the anchor points of accommodation ladders.

3.7.5.3 Support for mast structures fitted with navigation aids is to be provided as follows:

(1) adequate primary support members for the mast are to be arranged in the form of bulkheads, deep beams or girders. Such members are to be arranged below or close to the mast structure;

(2) in order to transmit the loads from the mast structure to the primary supporting members, underdeck stiffening members are to be arranged below the mast structure forming the attachment of the mast to the deck;

(3) the deck thickness may be required to be increased to provide an adequate thickness for the weld attachments.

3.7.5.4 Supporting structure for breakwaters is to be designed to withstand the same design load as the breakwater itself. It is to be suitable for transmitting the loads from the breakwater into the main supporting members of the ship. Efficient underdeck stiffening is to be provided in way of the breakwater structure that forms the deck connection.

3.7.5.5 The supporting structure of towing arrangements of tugs are to comply with the requirements of 10.5.3, Section 5 of Chapter 10 of this PART.

# Appendix 1 GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION

## 1 General

### 1.1 Application

1.1.1 The evaluation of bending moments, shear forces and support forces for the system rudder– rudder stock may be carried out for some basic rudder types as outlined in 2.1 to 2.5 of this Appendix.

## 2 The Forces on Rudder–Rudder Stock

### 2.1 Spade rudder

Data for the analysis

$l_{10}$ – $l_{30}$ = lengths of the individual girders of the system, in m;

$I_{10}$ – $I_{30}$ = moments of inertia of these girders, in cm$^4$.

Load of rudder body $P_R$:

$$P_R = C_R / (l_{10} 10^3) \qquad \text{kN/m}$$

Moments and forces

The moments and forces may be determined by the following formulae:

$$M_b = C_R(l_{20} + (l_{10}(2c_1 + c_2) / 3(c_1 + c_2)\ )) \qquad \text{Nm}$$

$$B_3 = \frac{M_b}{l_{30}} \qquad \text{N}$$

$$B_2 = C_R + B_3 \qquad \text{N}$$

where: $C_R$ — rudder force, in N.

The maximum moment, $M_c$, in top of the cone coupling as shown in Figure 2.1 is applicable for the connection between the rudder and the rudder stock.

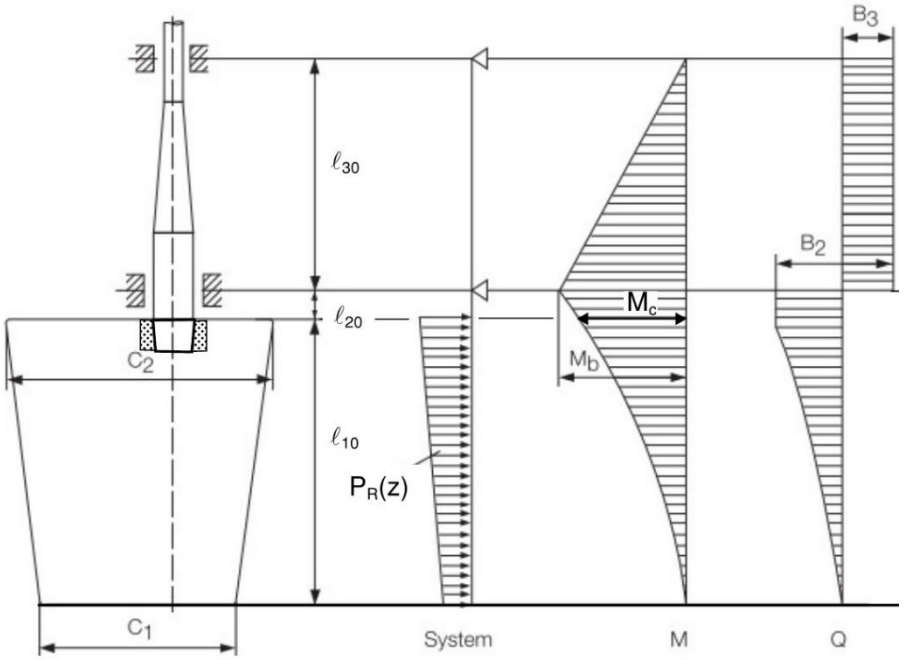



**Figure 2.1 Spade rudder**

### 2.2 Spade rudder with trunk

Data for the analysis

$l_{10}$ – $l_{30}$ = lengths of the individual girders of the system, in m;

$I_{10}$ – $I_{30}$ = moments of inertia of these girders, in cm$^4$.

Load of rudder body $P_R$:

$$P_R = C_R / ((l_{10} + l_{20})10^3) \qquad \text{kN/m}$$

Moments and forces

For a spade rudder with trunk extending inside the rudder, the strength is to be checked against the following two cases, and the moments and forces for the two cases defined above may be determined according to Figure 2.2(1) and 2.2(2), respectively.

(1) pressure applied on the entire rudder area;

Full rudder force $C_R = C_{R1} + C_{R2}$

total rudder torque $Q_R = Q_{R1} + Q_{R2}$

rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

(2) pressure applied only on rudder area below the middle of neck bearing.

Rudder force $C_{R2}$ corresponding to rudder torque $Q_{R2}$ acting at rudder blade area $A_2$ with rudders stock bending moment $M_b = M_{CR2}$

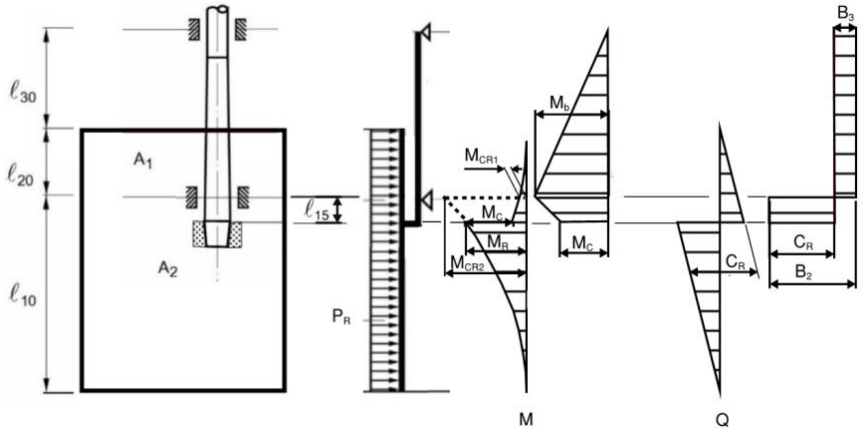



Figure 2.2(1)

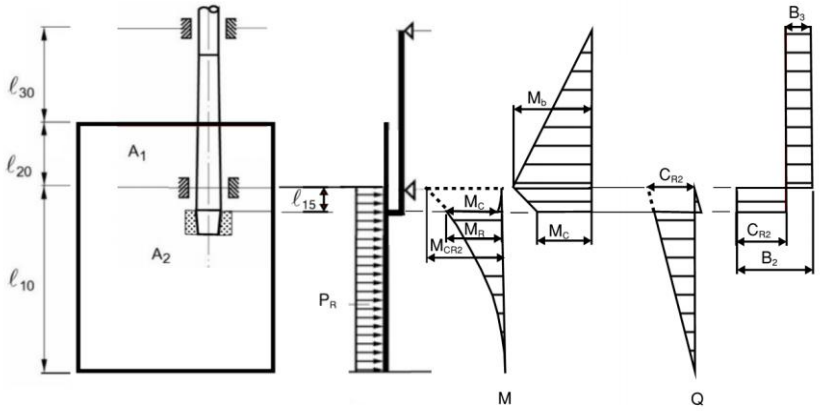



Figure 2.2(2)

$$M_{CR1} = C_{R1}(CG_{1Z} - l_{10}) \qquad \text{Nm}$$

$$M_{CR2} = C_{R2}(l_{10} - CG_{2Z}) \qquad \text{Nm}$$

where: $C_{R1}$: rudder force over the rudder blade area $A_1$;

$C_{R2}$: rudder force over the rudder blade area $A_2$;

$CG_{1Z}$: vertical position of the centre of gravity of the rudder blade area $A_1$;

$CG_{2Z}$: vertical position of the centre of gravity of the rudder blade area $A_2$;

$$C_R = C_{R1} + C_{R2} \qquad \text{N}$$

$$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30}) \qquad \text{N}$$

$$B_2 = C_R + B_3 \qquad \text{N}$$

### 2.3 Rudder supported by sole piece

Data for the analysis

$l_{10}$ – $l_{50}$ = lengths of the individual girders of the system, in m;

$I_{10}$ – $I_{50}$ = moments of inertia of these girders, in cm$^4$.

For rudders supported by a sole piece the length $l_{20}$ is the distance between lower edge of rudder body and centre of sole piece and $I_{20}$ the moment of inertia of the pintle in the sole piece.

$I_{50}$ = moment of inertia of sole piece around the $z$-axis, in cm$^4$;

$l_{50}$ = effective length of sole piece, in m;

Load of rudder body $P_R$:

$$P_R = C_R / (l_{10} 10^3) \qquad \text{kN/m}$$

$Z$ — spring constant of support in the sole piece;

$$Z = 6.18 \times I_{50} / l_{50}^3 \qquad \text{kN/m}$$

where: $C_R$ – rudder force, in N.

Moments and forces

Moments and shear forces are indicated in Figure 2.3.

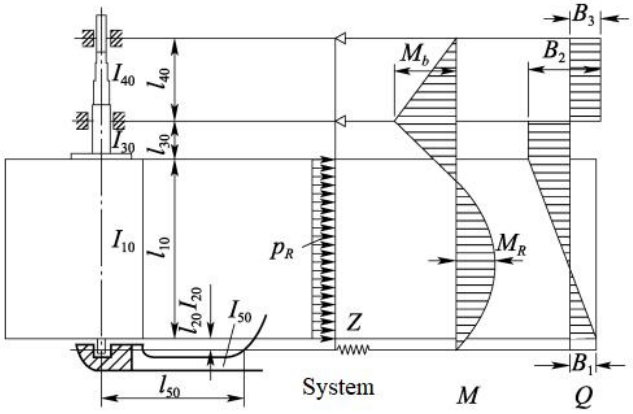



**Figure 2.3 Rudder supported by sole piece**

### 2.4 Semi spade rudder with one elastic support

Data for the analysis

$l_{10}$ – $l_{40}$ = lengths of the individual girders of the system, in m;

$I_{10}$ – $I_{40}$ = moments of inertia of these girders, in cm$^4$.

$Z$ — spring constant of support in the rudder horn:

$Z$=1/($f_b$+$f_t$) kN/m, for the support in the rudder horn (see Figure 2.4.1);

$f_b$ — unit displacement of rudder horn, in m, due to a unit force of 1 kN acting in the centre of support:

$$f_b = \frac{1.3h^3}{6.18 I_n} \qquad \text{m/kN (guidance value);}$$

$I_n$ — moment of inertia of horizontal section of rudder horn around the $x$-axis, in cm$^4$ (see also Figure 2.4.1);

$f_t$ — unit displacement due to torsion, in m/kN;

$$f_t = \frac{he^2 \sum u_i / t_i}{3.14 \times 10^8 F_T^2} \qquad \text{m/kN}$$

$F_T$ — mean sectional area of rudder horn, in m$^2$;

$u_i$ — breadth in [mm] of the individual plates forming the mean horn sectional area;

$t_i$ — thickness within the individual breadth $u_i$, in mm;

$h$ — Height of the rudder horn, in m, defined in Figure 2.4.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;

$e$ — distance as defined in Figure 2.4.2, in m, measured to $h/2$ of the height of the rudder horn;

Load of rudder body:

$$p_{R10}=\frac{C_{R2}}{l_{10}\times 10^3} \quad \text{kN/m}$$

$$p_{R20}=\frac{C_{R1}}{l_{20}\times 10^3} \quad \text{kN/m}$$

where: $C_R$, $C_{R1}$, $C_{R2}$, see 2.2 of this Appendix.

Moments and forces

Moments and shear forces are indicated in Figure 2.4.1.

Rudder horn

The loads on the rudder horn are as follows:

$M_b$ — bending moment = $B_1 z$, in N·m;

$M_{bmax}$= $B_1 h$, in N·m;

$Q$ — shear force = $B_1$, in N;

$M_T$(z) — torsional moment = $B_1 e(z)$, in N·m.

An estimate for $B_1$ is:

$B_1 = C_R b / (l_{20} + l_{30})$, in N.

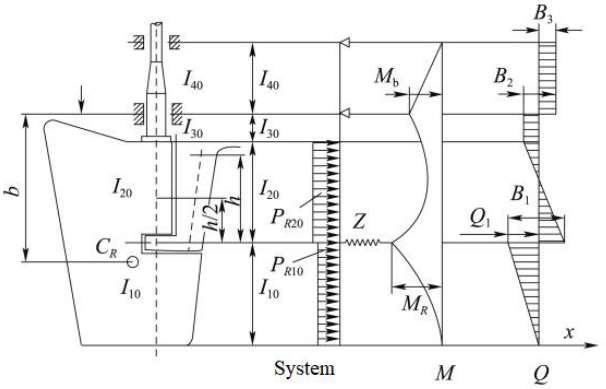



**Figure 2.4.1 Semi spade rudder with one elastic support**

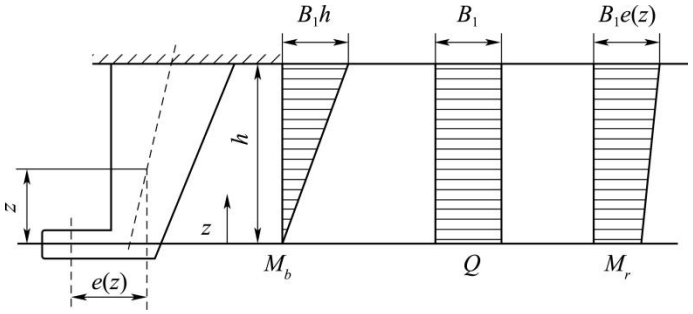



**Figure 2.4.2 Rudder horn of semi spade rudder with one elastic support**

## 2.5 Semi spade rudder with 2-conjugate elastic support

Data for the analysis

$K_{11}$, $K_{22}$, $K_{12}$: Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Figure 2.5.1).The 2-conjugate elastic supports are defined in terms of horizontal displacements, $y_i$, by the following equations:

at the lower rudder horn bearing:

$$y_1 = -K_{12}B_2 - K_{22}B_1$$

at the upper rudder horn bearing:

$$y_2 = -K_{11}B_2 - K_{12}B_1$$

where: $y_1$, $y_2$ — horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively;

$B_1$, $B_2$ — horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively;

$K_{11}$, $K_{22}$, $K_{12}$ — obtained, in m/kN, from the following formulae:

$$K_{11}=1.3\times\frac{\lambda^3}{3EJ_{1h}}+\frac{e^2\lambda}{GJ_{th}}$$

$$K_{22}=1.3\times\left[\frac{\lambda^3}{3EJ_{1h}}+\frac{\lambda^2(h-\lambda)}{2EJ_{1h}}\right]+\frac{e^2\lambda}{GJ_{th}}$$

$$K_{12}=1.3\times\left[\frac{\lambda^3}{3EJ_{1h}}+\frac{\lambda^2(d-\lambda)}{EJ_{1h}}+\frac{\lambda(h-\lambda)^2}{EJ_{1h}}+\frac{(h-\lambda)^3}{3EJ_{2h}}\right]+\frac{e^2h}{GJ_{th}}$$

where: $h$ — height of the rudder horn, in m, defined in Figure 2.5.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;

$\lambda$— length, in m, as defined in Figure 2.5.2. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant $Z$ for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part;

$e$ — rudder-horn torsion lever, in m, as defined in Figure 2.5.1 (value taken at $z = h/2$);

$J_{1h}$ — moment of inertia of rudder horn about the $x$-axis, in $m^4$, for the region above the upper rudder horn bearing. Note that $J_{1h}$ is an average value over the length $\lambda$ (see Figure 2.5.1);

$J_{2h}$ — moment of inertia of rudder horn about the $x$-axis, in $m^4$, for the region between the upper and lower rudder horn bearings. Note that $J_{2h}$ is an average value over the length $h - \lambda$ (see Figure 2.5.1);

$J_{th}$ — torsional stiffness factor of the rudder horn, in $m^4$. For any thin wall closed section:

$$J_{th}=\frac{4F_T^2}{\sum_i\frac{u_i}{t_i}} \quad m^4$$

$F_T$ — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in $m^2$;

$\mu_i$ — length, in mm, of the individual plates forming the mean horn sectional area;

$t_i$ — thickness, in mm, of the individual plates mentioned above.

Note that the $J_{th}$ value is taken as an average value, valid over the rudder horn height.

Load of rudder body:

$$p_{R10}=\frac{C_{R2}}{l_{10}\times10^3} \quad kN/m$$

$$p_{R20}=\frac{C_{R1}}{l_{20}\times10^3} \quad kN/m$$

where: $C_R$, $C_{R1}$, $C_{R2}$, see 2.2 of this Appendix.

Moments and forces

Moments and shear forces are indicated in Figure 2.5.1.

Rudder horn bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper supports provided by the rudder horn:

$$M_H = F_{A1}z \quad Nm$$

above the rudder horn upper-support:

$$M_H = F_{A1}z+F_{A2}(z-d_{lu}) \quad Nm$$

where:

$F_{A1}$ — support force at the rudder horn lower-support, in N, to be obtained according to Figure 2.5.1, and taken equal to $B_1$;

$F_{A2}$ — support force at the rudder horn upper-support, in N, to be obtained according to Figure 2.5.1, and taken equal to $B_2$;

$z$ — distance, in m, defined in Figure 2.5.2, to be taken less than the distance $h$, in m, defined in the same figure;

$d_{lu}$ — distance, in m, between the rudder-horn lower and upper bearings (according to Figure 2.5.1, $d_{lu} = h - \lambda$ ).

Rudder horn shear force

The shear force $Q_H$ acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

between the lower and upper rudder horn bearings:

$$Q_H = F_{A1} \quad \text{N}$$

above the rudder horn upper-bearing:

$$Q_H = F_{A1} + F_{A2} \quad \text{N}$$

where: $F_{A1}$, $F_{A2}$ — support forces, in N.

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper rudder horn bearings:

$$M_T = F_{A1} e(\text{z}) \quad \text{N·m}$$

above the rudder horn upper-bearing:

$$M_T = F_{A1} e(\text{z}) + F_{A2} e(\text{z}) \quad \text{N·m}$$

where: $F_{A1}$, $F_{A2}$ — support forces, in N;

$e(z)$ — torsion lever, in m, defined in Figure 2.5.2.

Rudder horn shear stress calculation

For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

$\tau_S$ — shear stress, in N/mm$^2$, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H} \quad \text{N/mm}^2$$

$\tau_T$ — torsional stress, in N/mm$^2$, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2F_T t_H} \quad \text{N/mm}^2$$

For solid rudder horn, $\tau_T$ is to be calculated based on the specific geometrical shape.

For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

$\tau_S$ — shear stress, in N/mm$^2$, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1} + F_{A2}}{A_H} \quad \text{N/mm}^2$$

$\tau_T$ — torsional stress, in N/mm$^2$, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2F_T t_H} \quad \text{N/mm}^2$$

For solid rudder horn, $\tau_T$ is to be considered on a case by case basis.

where:

$F_{A1}$, $F_{A2}$ — support forces, in N;

$A_H$ — effective shear sectional area of the rudder horn, in mm$^2$, in $y$-direction;

$M_T$ — torque, in N·m;

$F_T$ — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m$^2$;

$t_H$ — Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of $\tau_T$ is obtained at the minimum value of $t_H$.

Rudder horn bending stress calculation

For the generic section of the rudder horn within the length $h$, the following stresses are to be calculated:

$\sigma_B$ — bending stress, in N/mm$^2$, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X} \quad \text{N/mm}^2$$

where: $M_H$ — bending moment at the section considered, in N·m;

$W_X$ — section modulus, in cm$^3$, around the $x$-axis (see Figure 2.5.2).

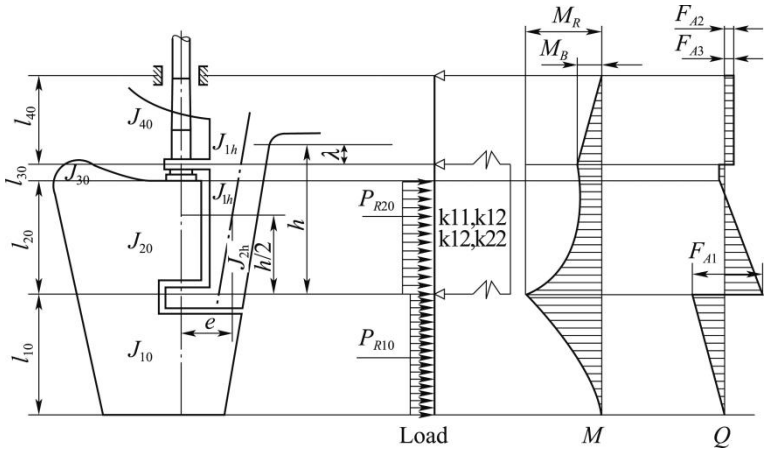



**Figure 2.5.1**

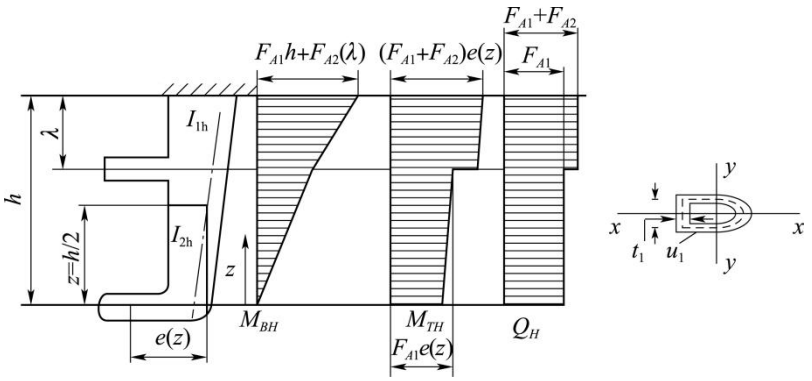



**Figure 2.5.2**

# Appendix 2 DIRECT MOORING ANALYSES

1 General

1.1 As an alternative to the requirements for mooring lines in 3.2.4 of this Chapter, direct mooring analysis may be performed to determine the necessary mooring restraint, i.e. number and strength of mooring lines.

Direct analyses allow to optimize mooring equipment and arrangement for the individual ship and the port mooring facilities typical for the considered ship type and size.

2 Documentation

2.1 The calculations should be documented in a report. The report should include all assumptions made in calculations for the finally chosen mooring equipment, including lines, and its arrangement, reflected in the mooring arrangement plan.

3 Analysis methodology

3.1 Three dimensional quasi-static calculations should be performed to determine the acting mooring line forces. As a minimum, loads from wind and current should be accounted for in the analysis. Geometrical and material nonlinearities of mooring lines and fenders or breasting dolphins should be considered. An iterative calculation procedure should be applied to arrive at a converged solution with forces acting on mooring lines and on fenders or breasting dolphins being in equilibrium with forces and moments applied to the ship.

4 Environmental conditions

4.1 Mooring line forces should be calculated for environmental conditions given in 3.2.4.3 of this Chapter. Additional loads, e.g. wave loads or cross currents, or increased wind and current loads may be considered for certain ship types or for specific ports intended to be regularly called.

5 Steps to be taken in a direct mooring analysis

Direct assessment of mooring forces and determination of the necessary number and strength of mooring lines comprise the following steps:

(1) Determine port mooring facilities representative for the considered ship type and size

(2) Determine shipboard mooring equipment and arrangement

(3) Determine mooring line type(s) to be used

(4) Determine mooring layout(s) to be assessed

(5) Determine ship loading condition(s) to be assessed

(6) Select or determine wind and current drag coefficients

(7) Determine wind and current forces and moments

(8) Compute forces acting on all mooring line

(9) Determine necessary strength of mooring lines

(10) If strength of mooring lines should be altered, modify steps (2), (3) and/or (4) with or without changing the number of mooring lines and repeat steps (8) and (9)

5.1 Port mooring facilities

5.1.1 Characteristics of port mooring facilities have strong influence on the resulting mooring line forces. Mooring analysis should be performed for port mooring facilities representative for the considered ship type and size, i.e. type of berth, type and arrangement of hooks/bollards, type and arrangement of fenders or breasting dolphins and height of pier above waterline.

5.1.2 Fenders or breasting dolphins in many cases may not affect the critical mooring line loads. Hence, initially, generic fender or dolphin arrangements and infinitely stiff load deformation characteristics may be considered. If no fender or dolphin loads occur for load cases yielding the critical mooring line loads, more specific fender or dolphin arrangements and characteristics may be omitted.

5.1.3 If there are substantially different port mooring facilities typically encountered by the considered ship type, additional calculations should be performed to consider these variations.

5.2 Shipboard mooring equipment and arrangement

5.2.1 The mooring equipment and arrangement need to be chosen for the mooring analysis, i.e. location of mooring decks and location of mooring winches and fairleads. As a starting point, mooring equipment for the number of lines as determined by 3.2.4 of this Chapter may be chosen.

5.3 Mooring lines

5.3.1 The mooring analysis should apply the mooring line type(s) intended to be supplied with the vessel. The geometrical and material nonlinearities of the mooring lines should be considered by the mooring analysis. Load-deflection characteristics of mooring lines can be taken from data sheets of rope manufacturers. If given, characteristics of the broken-in ropes should be applied.

5.3.2 To achieve a good distribution of mooring line forces, mooring line type and characteristics should be at least same for lines in the same service, e.g. for head and stern lines, breast lines and spring lines. For

very stiff mooring lines, e.g. made of steel or high modulus synthetic fibers, the use of elastic tails should be considered to enhance the elasticity in the mooring system and taken into account for the mooring analysis.

5.4 Mooring layout

5.4.1 For the assessment of forces acting on mooring lines, a realistic mooring layout needs to be assumed, i.e. for each mooring line it needs to be determined from which bollard or winch, along which path, through which fairlead it is led and to which shoreside hook or bollard it is connected. Inboard parts of the mooring lines (between fairlead and shipboard fixation point) contribute to the elongation behavior of the line and should be included in the analysis.

5.4.2 The maximum number of lines connected to one shore mooring point needs to be limited to not load the shore side mooring points unrealistically high. For multipurpose piers the number of lines per shore bollard should be limited to three. For other types of berths, the number mooring lines per shore mooring point is also limited, e.g., by the available number of hooks. Reasonable assumptions should be made based on typical berth types encountered by the considered ship type.

5.4.3 Alternative mooring layouts should also be assessed, considering possible and reasonable options to moor the ship to the assumed port mooring facilities. Also, a different position of the ship relative to the shoreside mooring bollards/hooks should be assessed to find the critical mooring line loads for the normal operation of the ship. Exemptions may be given to e.g. tankers, LNG carriers or ferries if typically moored in the same position relative to the shoreside mooring facilities.

5.5 Loading conditions

5.5.1 Mooring line forces should be calculated for loading conditions given in 3.2.4.3 of this Chapter.

5.6 Wind and current drag coefficients

5.6.1 To calculate the wind and current forces and moments acting on the ship, wind and current drag coefficients are needed for the considered ship type, size and loading condition. Drag coefficients should be as specific as possible for the considered ship and loading conditions.

5.6.2 There are different sources for drag coefficients. Some Industry Guidelines provide drag coefficients for tankers and LNG carriers which can be applied. Due to the similarity of hull forms and superstructures, these coefficients may also be used for bulk carriers and ore carriers. For other ship types drag coefficients may be taken from the literature, if available, or can be determined by CFD calculations or model tests. CFD calculations are to be justified with suitable validation and sensitivity studies.

5.6.3 There are some effects that can influence the drag coefficients, i.e. blockage (limited under keel clearance, solid quay walls), ship draft and wind shielding by solid quays and buildings or cargo stored on quays (e.g. container stacks). Effects from blockage and ship draft can only be accounted for by appropriate coefficients. Drag coefficient should be chosen or determined for realistic water depth to draft ratios and for the considered ship draft(s). Some Industry Guidelines provide current drag coefficients for ballast and loaded draft conditions and for different water depth to draft ratios. Wind shielding effects are typically not considered by the wind drag coefficients. The effect of wind shielding of solid quays may be considered by an equivalent reduction of the lateral wind area of the ship. Shielding by buildings or cargo stored on quays should not be considered as their presence is imponderable.

5.7 Calculation of wind and current forces and moments

5.7.1 Wind and current forces and moments can be calculated for the given environmental conditions with the geometrical particulars of the considered ship and the selected drag coefficients. Usually, the forces in longitudinal and transversal directions as well as the moment about the vertical ship axis (yaw) are calculated.

5.7.2 Wind forces and moments should be calculated for all directions in intervals of preferably 15°, but not more than 30°. Current forces and moments should be calculated for selected directions as per 3.2.4.3 of this Chapter. For ships regularly moored to non-solid piers or jetties, cross current may need to be considered in addition.

5.8 Calculation of mooring line forces

5.8.1 For all considered scenarios and all combinations of applied environmental conditions, the maximum mooring line force should be determined for groups of lines in the same service.

5.8.2 In case of all lines are intended to be attached to winches, brake rendering can be considered to better distribute line loads among all lines in a group of lines in the same service. Then, the average mooring line force of a group of lines may be determined and taken as mooring line force used to determine the necessary strength of the mooring lines according to section 5.9.

5.9 Strength of mooring lines

5.9.1 The necessary strength of mooring lines, i.e., the Ship Design Minimum Breaking Load ($MBL_{SD}$), results from the calculated maximum mooring line force ($F_{L,\,max}$) divided by the Work Load Limit ($WLL$)

factor of mooring lines. The *WLL* factor and the resulting MBLSD for different mooring line materials are shown in the below table.

***WLL* factor and $MBL_{SD}$** **Table 5.9.1**

| Mooring line material | *WLL* factor | $MBL_{SD}$ |
|---|---|---|
| Steel wire | 0.55 | $1.82 \times F_{L,max}$ |
| Synthetic fibers | 0.5 | $2.0 \times F_{L,max}$ |

5.9.2 Preferably, all lines supplied to the ship should have the same characteristics and strength to avoid confusion of lines. However, for significantly different maximum calculated line loads, lines in different service may also have different strength and characteristics, e.g. for head and stern lines other than for spring lines.

# Appendix 3 DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT

1 General

1.1 As an alternative to the prescriptive approach described in 3.2.1.2 of this Chapter direct force calculation may be performed to determine the necessary anchoring equipment for monohull ships with length less than 90m.

2 Total force $F_{EN}$

2.1 The total force (static + dynamic) $F_{EN}$ , in kN, induced by wind and current acting on monohull in anchoring condition as defined in A1.1 may be calculated as follows:

$$F_{EN} = 2(F_{SLPH} + F_{SH} + F_{SS})$$

where: $F_{SLPH}$ ——Static force on wetted part of the hull due to current;

$F_{SH}$ ——Static force on hull due to wind;

$F_{SS}$ ——Static force on superstructures due to wind.

2.1.1 Calculation of $F_{SLPH}$

Static force on wetted part of the hull due to current $F_{SLPH}$ , in kN, is defined according to the following formula:

$$F_{SLPH} = \frac{1}{2}\rho C_f S_m V_c^2 10^{-3}$$

where: $\rho$ ——Water density, equal to 1025kg/m$^3$;

$C_f$ ——Coefficient equal to:

$$C_f = (1+k)\frac{0.075}{(\log R_e - 2)^2}$$

where: $R_e$ ——Reynolds number equal to:

$$R_e = \frac{(V_c L_{WL})}{1.054 \cdot 10^{-6}}$$

$k$ ——Coefficient equal to:

$$k = 0.017 + 20\frac{C_{bWL}}{L_{WL}^2 T^{-0.5} B_{WL}^{-1.5}}$$

$C_{bWL}$ ——block coefficient at waterline equal to:

$$C_{bWL} = \frac{\Delta}{1.025 L_{WL} B_{WL} T}$$

where: $\Delta$ ——Moulded displacement at waterline, in m$^3$;

$S_m$ ——Total wetted surface of the part of the hull under draught, in m$^2$. The value of $S_m$ is to be given by the Designer. When this value is not available, $S_m$ may be taken equal to $6 \cdot \Delta^{2/3}$ ;

$V_c$ ——Speed of the current, in m/s.

2.1.2 Calculation of $F_{SH}$

Static force on hull due to wind $F_{SH}$, in kN, is defined according to the following formula:

$$F_{SH} = \frac{1}{2}\rho(C_{hfr}S_{hfr} + 0.02S_{hlat})V_W^2 10^{-3}$$

where: $\rho$ ——Air density, equal to 1.22kg/m$^3$;

$V_W$ ——Speed of the wind, in m/s;

$S_{hfr}$ ——Front surface of hull and bulwark if any, in m$^2$, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

$S_{hlat}$ ——Partial lateral surface of one single side of the hull and bulwark if any, in m$^2$, through the overall length of the ship, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. In Figure 2.1.2, B is the breadth of the hull, in m.

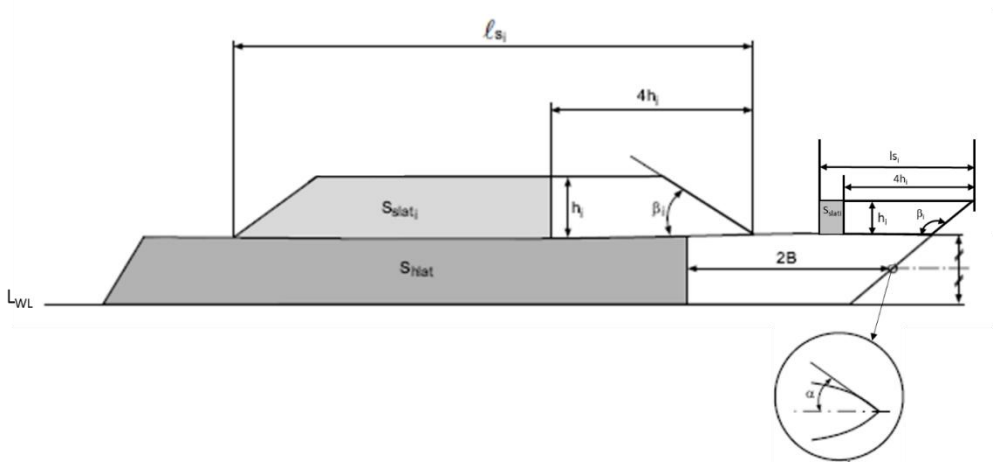



**Figure 2.1.2**

$C_{hfr}$ ——Coefficient equal to $0.8\sin\alpha$, with $\alpha$ defined in Figure 2.1.2;

The upper part of the hull is the part extending from side to side to the uppermost continuous deck extending over the ship length.

2.1.3 Calculation of $F_{SS}$

(1) General case

Static force on superstructures and deckhouses due to wind $F_{SS}$, in kN, is defined according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{sfr_i}S_{sfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: $\rho$ ——Air density, equal to 1.22kg/m$^3$;

$V_W$ ——Speed of the wind, in m/s;

$S_{sfr_i}$ ——Front surface of tier i (superstructure or deckhouse, including bulwark if any), in m$^2$, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

$S_{slat_i}$ ——Partial lateral surface of one single side of tier i (superstructure or deckhouse, including bulwark if any), in m$^2$, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. When $4h_i \geq l_{si}$, $S_{slat_i}$ is to be taken equal to 0;

$C_{sfr_i}$ ——Coefficient equal to $0.8\sin\beta_i$, with $\beta_i$ defined in Figure 2.1.2 without being greater than 90°;

(2) Superstructures in the forward part of the ship

When superstructures are located in the front of the hull with front and side walls of superstructures in the

continuity of the side shell, the static force induced by wind applied on these superstructures $F_{SS}$, in KN, is defined as the sum of the forces applied to each superstructure tier according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{hfr_i}S_{hfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: $S_{hfr_i}$ ——Front surface of tier i of the superstructure, in $m^2$, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship

$C_{hfr_i}$ ——Coefficient equal to $0.8\sin\alpha_s$, with $\alpha_s$ defined in Figure 2.1.2 and measured at mid height of the superstructure tier located in the front of the hull.

The static force is to be added to the static force calculated for the other superstructures and deckhouses according to 2.1.3(1) of this Appendix.

3 Anchor weight

3.1 The individual mass of anchor, in kg, is to be at least equal to:

for ordinary anchor: $P = (F_{EN}/7)\cdot 10^2$

for high holding power anchor: $P = (F_{EN}/10)\cdot 10^2$

for very high holding power: $P = (F_{EN}/15)\cdot 10^2$

4 Chain cable

4.1 Stud link chain cable scantling

Chain cable diameters are to be based on the minimum breaking load *BL* and proof load *PL* of steel grades.

**Chain Cable Diameters** **Table 4.1**

| | CCS Grade 1 | CCS Grade 2 | CCS Grade 3 |
|---|---|---|---|
| *BL* | $6F_{EN}$ | $6.8F_{EN}$ | $7.5F_{EN}$ |
| *PL* | 0.7*BL* | | |

The chain cable scantling is to be consistent with the mass of the associated anchor. In case the anchor on board is heavier by more than 7% from the mass calculated in 3.1 of this Appendix, the value of $F_{EN}$ to take into account for the calculation of BL and PL is to be deduced from the actual mass of the anchor according to the formulae in 3.1 of this Appendix.

4.2 Length of individual chain cable

The length of chain cable $L_{cc}$, in m, linked to each anchor is to be at least equal to:

when P<180, $L_{cc} = 30\ln(\mathrm{P}) - 42$

when P≥180, $L_{cc}$ to be selected according to Table 3.2.1.1(2) of this Chapter.

where: P: Anchor weight, in kg, defined in 3.1 of this Appendix for an ordinary anchor according to the considered case.

# CHAPTER 4 STRENGTHENING FOR NAVIGATION IN ICE

## Section 1 GENERAL PROVISIONS

### 4.1.1 General requirements

4.1.1.1 For structural strengthening for navigation in ice, the requirements are to be based on the ice class notations intended to be attained by shipowners. The ice class notations and relevant provisions are given in Chapter 4 of PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

4.1.1.2 For ships without ice class notations or non-classed ships, structural strengthening for navigation in ice is not a compulsory rule requirement, but appropriate anti-ice structural strengthening measures are to be taken for safe navigation in ice.

# CHAPTER 5 DOUBLE HULL OIL TANKERS

## Section 1 GENERAL PROVISIONS

### 5.1.1 Application

5.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of double hull oil tankers having double bottoms and with machinery spaces being situated aft, intended to carry crude oil and petroleum products having a flash point not exceeding 60℃ (closed cup test) and a Reid vapour pressure which is below the atmospheric pressure. If not covered in this Chapter, the relevant requirements of Chapters 2 and 6 of this PART are to be complied with.

5.1.1.2 The double hull oil tankers intended to carry oils having a flash point exceeding 60℃ (closed cup test) only are also to comply with the requirements of this Chapter. Where the temperature of heated cargo oils is at least 10℃ below their flash point, the requirements of 5.1.3.4 to 5.1.3.8 and 5.4.1.3 of this Chapter may not be applicable. The scantlings and arrangements of tankers intended for cargoes other than the above oil will be specially considered in relation to the characteristics and density of the cargo. For oil tankers intended for the carriage of liquids with a density greater than 1.025 $t/m^3$, the structural strength of the cargo tank region is to be specially considered.

### 5.1.2 Plans and documents

5.1.2.1 The following plans and documents are to be submitted for approval in addition to those required in Section 1 of Chapter 2 of this PART:

(1) Connections of longitudinals with other members;

(2) Details at intersections of transverse and longitudinal framing;

(3) Closing arrangements for all deck openings;

(4) Any dry cargo tanks or tanks for water ballast only, which are empty in the fully loaded condition, are to be indicated on the principal structural and arrangement plans;

(5) The location of all openings in the deck is to be indicated on the structural plan of deck.

### 5.1.3 Limitations of size and arrangement of cargo tanks

5.1.3.1 The wing cargo tank mentioned here refers to a cargo tank, with inner hull forming one of its boundaries, of an oil tanker with oil-tight longitudinal bulkheads. Other cargo tanks are referred to as centre tanks.

5.1.3.2 With regard to subdivision, size of cargo tanks, distance from side shell to inner hull and depth of double bottom, the requirements of Section 8, Chapter 1 of this PART are to be complied with.

5.1.3.3 Segregated ballast tanks, dedicated clean ballast tanks and slop tanks are to be arranged in compliance with the requirements of Section 8, Chapter 1 of this PART.

5.1.3.4 Cofferdams are to be provided at the forward and aft ends of the cargo tanks region so as to separate oil tanks from engine rooms, boiler rooms, dry cargo holds and accommodation spaces. Cofferdams are to have an adequate spacing between their end bulkheads to permit easy access and cover the whole area of the end bulkheads of the cargo tank region. The spacing between the bulkheads is in general not to be less than 760 mm. For small oil tankers, where it is difficult to arrange cofferdams, smaller spacing may be accepted, but it is not to be less than 600 mm. Where a corner-to-corner situation occurs, protection may be formed by a diagonal plate across the corner. A pump room, water ballast tank or oil fuel tank may be accepted in lieu of a cofferdam.

5.1.3.5 Any access to spaces adjacent to a cargo tank is to be from the open deck. Passages or tunnels passing through or adjacent to a cargo tank and not separated from it by a cofferdam, are to be provided with mechanical ventilation, and any access is also to be from the open deck.

5.1.3.6 Where the lower portion of the pump room is recessed into the machinery space, the height of the recess is not, in general, to exceed 1/3 of the moulded depth above the baseline except that in the case of ships of not more than 25,000 metric tons deadweight, a recess in excess of such height, but not exceeding one half of the moulded depth of the ship may be permitted.

5.1.3.7 The wheelhouse, where fitted above the cargo tank region, is to be separated from the cargo tank deck by means of an open space with a height of at least 2 m.

5.1.3.8 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of not less than 300 mm in height extending from side to side. Special consideration is to be given to the arrangements associated with

stern loading and unloading for the prevention of deck spill from flowing over board.

### 5.1.4 Structural details

5.1.4.1 For oil tankers of over 65 m in length, the deck, bottom and inner bottom within the cargo tank region of tankers are to be longitudinally framed. Where the length of ship exceeds 190 m, the side shell, inner hull and longitudinal bulkheads are generally to be longitudinally framed. The hull structures beyond the cargo tank region may be framed either transversely or longitudinally. Constructional arrangements are to be made to ensure a gradual transition from the longitudinal framing to the transverse framing.

5.1.4.2 The typical midship section of double hull oil tankers and the structural members referred to in this Chapter are as shown in Figure 5.1.4.2.

5.1.4.3 Cargo tanks are enclosed by double bottom, wing ballast tank, empty cofferdams and deck. The loading of cargo and fuel oils is not permitted in the double bottoms and wing ballast tanks.

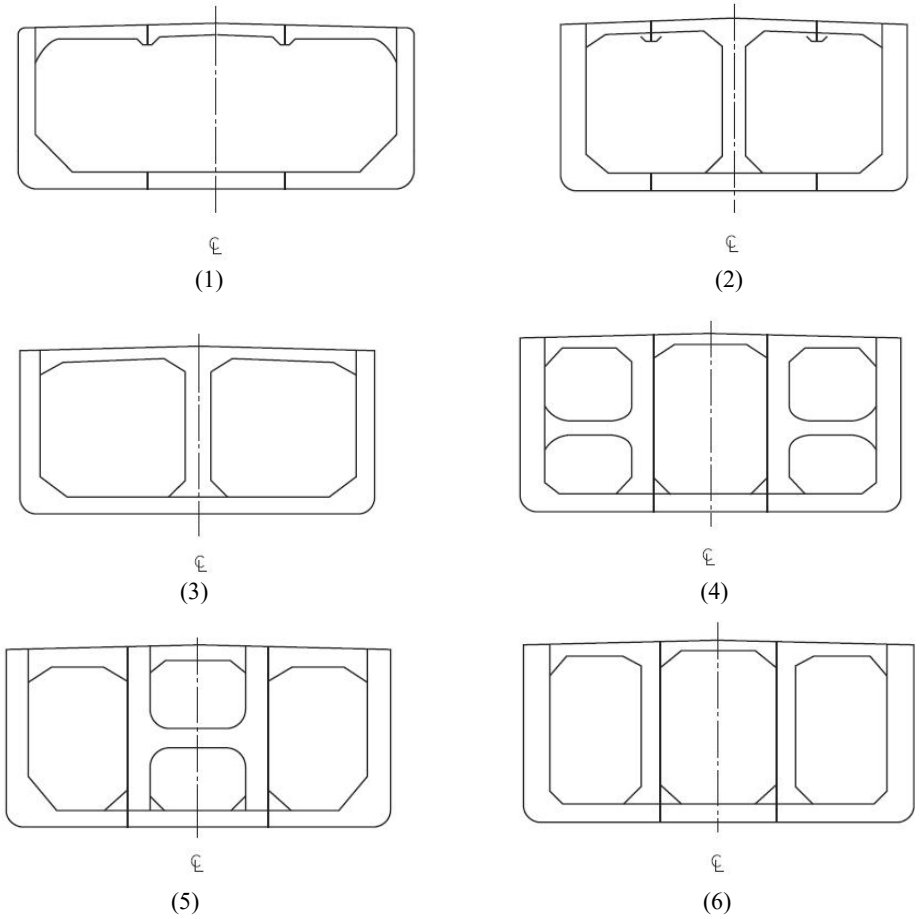
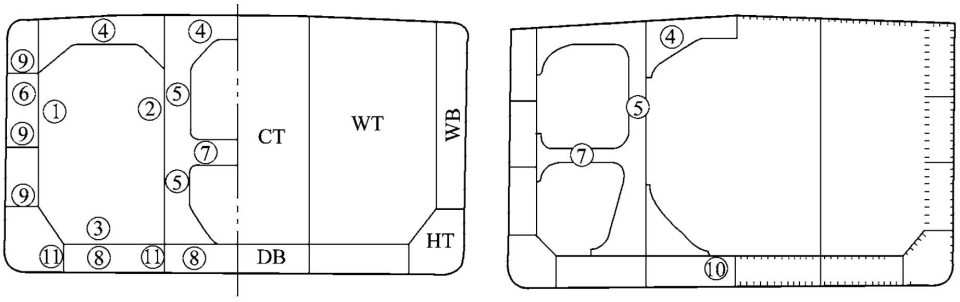
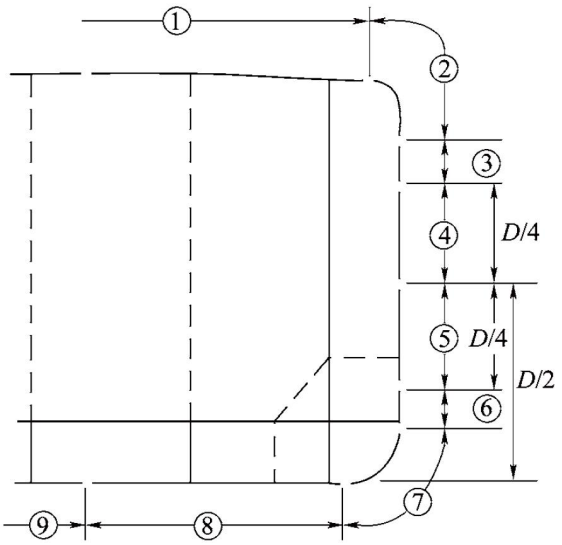



**Figure 5.1.4.2(1) Typical Midship Section**




1— Inner hull; 2 — Longitudinal bulkhead; 3 — Inner bottom; 4 — Deck transverse; 5 — Vertical web on longitudinal bulkhead; 6 — Vertical web in wing ballast tank; 7 — Cross ties; 8 — Floor; 9 — Horizontal girder in wing ballast tank; 10 — Double bottom girder; 11 —Double bottom side girder; WB — Wing ballast tank; WT — Wing cargo tank; CT — Centre cargo tank; HT — Hopper tank; DB — Double bottom




1— Deck plating; 2 — Deck stringer and sheer strake; 3 — Side shell plating 1; 4 — Side shell plating 2; 5 — Side shell plating 3; 6 — Side shell plating 4; 7 — Bilge plating; 8 — Bottom shell plating; 9 — Plate keel

**Figure 5.1.4.2(2) Typical Midship Section and Structural Members**

### 5.1.5 Minimum thickness

5.1.5.1 Within the cargo tank region (including wing ballast tanks, empty cofferdams at the ends of the cargo tank region or between cargo tanks), the minimum thickness $t$ of primary member webs and face plates, shell plating, deck plating, bulkhead plating and inner hull plating is not to be less than that obtained from the following formula:

$$t = 6.5 + L/50 \quad \text{mm, but not less than 7.5 mm}$$

where: $L$ — length of ship, in m, taken not greater than 300 m.

The minimum thickness of secondary structural members are also to comply with the requirements mentioned above, but need not be greater than 11 mm.

5.1.5.2 The minimum thickness $t$ of the members in pump rooms, cofferdams and other void spaces may be 1 mm less than that required in 5.1.5.1, but not less than 7.5 mm.

### 5.1.6 Longitudinal strength of double hull oil tankers

5.1.6.1 Double hull oil tankers are to comply with the longitudinal strength requirements specified in Section 2, Chapter 2 of this PART.

### 5.1.7 Direct calculations and fatigue assessment of hull structural strength

5.1.7.1 For oil tankers of 150 m or over in length, direct strength calculations are to be carried out for the primary members (longitudinal or transverse) in the cargo tank region according to the Appendix 1 of this Chapter.

5.1.7.2 For oil tankers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo tank region in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of hopper tanks or inner shell to inner bottoms.

## Section 2 SHELL PLATING

### 5.2.1 General requirements

5.2.1.1 The formulae of this Section are applicable to the determination of thickness of longitudinally framed bottom shell plating, plate keels, bilge plating, side shell plating and shear strakes.

### 5.2.2 Bottom shell plating

5.2.2.1 The thickness $t$ of bottom shell plating within $0.4L$ amidships is not to be less than that obtained

from the following formulae:

$$t_1 = 0.052s(L_1 + 170)\sqrt{\frac{F_b}{K}} \text{ mm}$$

$$t_2 = 4.9s\sqrt{(h_w + 0.8d)K} \text{ mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken as not less than standard spacing of longitudinals;
$d$ — draught, in m;
$L_1$ — length of ship, in m, to be taken as not more than 190 m;
$F_b$ — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
$K$ — material factor;

$$h_w = 0.2B^{0.66} + \left(0.25 + \frac{0.82}{\sqrt{L}}\right)C$$

where: $B$ — breadth of ship, in m;
$L$ — length of ship, in m;
$C$ — see 2.2.3.1 of Section 2, Chapter 2 of this PART.

### 5.2.3 Plate keels

5.2.3.1 The breadth $b$ of the plate keel within the cargo tank region is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \text{ mm}$$

And the thickness $t$ is not to be less than:

$$t = t_0 + 2.0 \text{ mm} \quad L \le 190 \text{ mm}$$
$$t = t_0 + 3.0 \text{ mm} \quad L > 190 \text{ mm}$$

where: $L$ — length of ship, in m;
$t_0$ — the thickness of the bottom shell plating, in mm, as determined in 5.2.2.1 of this Section.

### 5.2.4 Bilge plating

5.2.4.1 The thickness $t$ of bilge plating within $0.4L$ amidships is to be the same as that of bottom shell plating.

5.2.4.2 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at bilge, the thickness of bilge plating is not to be less than $\frac{rF_b}{165K}$ ( $r$ being the radius of the bilge, in mm, $K$ being material factor, and $F_b$ being reduction factor of bottom). The framing associated with such an arrangement is to comply with the requirements of 5.4.4.1 of Section 4 of this Chapter.

### 5.2.5 Side shell plating

5.2.5.1 Where longitudinal side framing is adopted, the thickness $t$ of side shell plating within $0.4L$ amidships is to comply with the following requirements:

(1) The thickness $t$ of side shell plating above $\frac{3}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.058s(L + 110)\sqrt{\frac{F_d}{K}} \text{ mm}$$

$$t_2 = 7.1s\sqrt{h_w K} \text{ mm}$$

where: $s$ — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;
$L$ — length of ship, in m, to be taken as not greater than 190 m;
$F_d$ — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
$K$ — material factor;
$h_w$ — see 5.2.2.1 of this Section.

(2) The thickness $t$ of side shell plating below $\frac{1}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L + 110)\sqrt{\frac{F_b}{K}} \text{ mm}$$

$$t_2 = 5.2s\sqrt{(h_w + 0.8d - 0.2D)K} \text{ mm}$$

where: $s$ — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;

$d$ — draught, in m;
$F_b$ — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
$L$ — length of ship, in m, to be taken not more than 190 m;
$K$ — material factor;
$h_w$ — see 5.2.2.1 of this Section.

(3) The thickness $t$ of side shell plating above $\frac{3}{4}D$ and below $\frac{1}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = \text{s}\,[t_{11} + (t_{12} - t_{11})h] \quad \text{mm}$$
$$t_2 = \text{s}\,[t_{21} + (t_{22} - t_{21})h] \quad \text{mm}$$

where: $t_{11} = \dfrac{t_{1,z=0.25D}}{s_{z=0.25D}}$

$t_{12} = \dfrac{t_{1,z=0.75D}}{s_{z=0.75D}}$

$t_{21} = \dfrac{t_{2,z=0.25D}}{s_{z=0.25D}}$

$t_{22} = \dfrac{t_{2,z=0.75D}}{s_{z=0.75D}}$

$h = \dfrac{z - 0.25D}{0.5D}$

$s_{z=0.25D}$ — spacing of longitudinals, in m, at 0.25$D$, not to be less than the standard spacing of longitudinals;
$s_{z=0.75D}$ — spacing of longitudinals, in m, at 0.75$D$, not to be less than the standard spacing of longitudinals;
$t_{1,z=0.25D}$ — thickness $t_1$ of plating, in mm, at 0.25$D$;
$t_{1,z=0.75D}$ — thickness $t_1$ of plating, in mm, at 0.75$D$;
$t_{2,z=0.25D}$ — thickness $t_2$ of plating, in mm, at 0.25$D$;
$t_{2,z=0.75D}$ — thickness $t_2$ of plating, in mm, at 0.75$D$;
$s$ — spacing of longitudinals at the point under consideration, in m, not to be less than the standard spacing of longitudinals;
$D$ — moulded depth, in m;
$z$ — distance between the point under consideration and baseline.

(4) In calculation of $t_1$, except the minimum range of high tensile steel stipulated in Section 2 of Chapter 2, the material factor $K$ may be taken as 1.

### 5.2.6 Sheer strakes

5.2.6.1 The breadth of the sheer strakes is to meet the requirements of 2.3.5.1 of Section 3, Chapter 2 of this PART.

5.2.6.2 The thickness $t$ of sheer strakes within 0.4$L$ amidships is not to be less than that obtained from the following formulae, also not to be less than that of the adjacent side shell plating:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$
$$t_2 = 0.9s\sqrt{(L + 75)K} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;
$L$ — length of ship, in m;
$L_1$ = $L$, $L$ being the length of ship, in m, to be taken not more than 190 m in calculation;
$K$ — material factor;
$F_d$ — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

### 5.2.7 End shell plating

5.2.7.1 The thickness of shell plating at ends is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART.

# Section 3 DECKS

### 5.3.1 General requirements

5.3.1.1 The formulae of this Section are applicable to the determination of thickness of longitudinally-framed strength deck plating within 0.4$L$ amidships.

### 5.3.2 Strength deck plating

5.3.2.1 The thickness $t$ of strength deck plating within 0.4$L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;
$L$ — length of ship, in m;
$L_1$ = $L$, $L$ being the length of ship, in m, to be taken not more than 190 m in calculation;
$K$ — material factor;
$F_d$ — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

5.3.2.2 The thickness of strength deck plating at ends is to comply with the relevant requirements of Section 4 of Chapter 2 of this PART.

### 5.3.3 Connections of deck stringers to sheer strakes

5.3.3.1 The connections of deck stringers to sheer strakes are to comply with the relevant requirements of Section 3 of Chapter 2 of this PART.

# Section 4 DOUBLE BOTTOM STRUCTURE

### 5.4.1 General requirements

5.4.1.1 The scantlings and arrangement of the double bottoms in cargo tanks are to be as required in Section 6, Chapter 2 of this PART, except as otherwise specified in this Section.

5.4.1.2 The integrity of the double bottom is to be maintained. Manholes are not to be fitted on the inner bottom of cargo tanks and the access is not to be via the engine room. Access to double bottom tanks is to be provided by trunks from the exposed deck.

5.4.1.3 Arrangements are to be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to eliminate flammable gases which possibly exist in these tanks.

5.4.1.4 Where a duct keel or pipe tunnel is fitted, the duct keel or pipe tunnel is not to be interconnected with the engine room. At least two accesses to open deck are to be provided at a maximum distance from each other. Where one of such accesses passes through a pump room, the access from the pump room to the duct keel or pipe tunnel is to be provided with a watertight cover.

5.4.1.5 Manholes are to be fitted in floors and side girders in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART as well as those in Section 8, Chapter 1 of this PART.

5.4.1.6 Drain holes and vent holes are to be fitted in floors, side girders, bottom longitudinals and inner-bottom longitudinals in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART.

### 5.4.2 Bottom girders

5.4.2.1 The centre girders or duct keels are to be arranged at the longitudinal centerline of double bottoms. Side girders are also to be provided at sides.

5.4.2.2 Girders are to be provided below lower stools of the longitudinal or longitudinal corrugated bulkhead, whereas side girders are to be provided below hopper tank slope plating.

5.4.2.3 In way of vertically corrugated transverse bulkheads supported by stools, additional local girders are to be arranged in accordance with the requirements in 5.9.3.2 of Section 9 of this Chapter.

5.4.2.4 The thickness of centre keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = (0.008h_0 + 1.0)\sqrt{K} \quad \text{mm}$$

where: $h_0$ — considered height of centre keels, in mm, see 2.6.2.1 of Section 6, Chapter 2 of this PART;
$K$ — material factor.

5.4.2.5 The thickness of side plating of duck keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = 0.008 h_0 \sqrt{K} \qquad \text{mm}$$

where: $h_0$, $K$— the same as that in 5.4.2.4 of this Section.

5.4.2.6 The thickness of side girders is not to be less than that obtained from the following formula, and is to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART where side girders are watertight:

$$t = (0.007 h_0 + 1.0)\sqrt{K} \quad \text{mm, but need not be greater than 14 mm}$$

where: $h_0$, $K$ — the same as that in 5.4.2.4 of this Section.

5.4.2.7 For ships whose breadth is greater than 12 m, but not greater than 20 m, at least one side girder is to be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks). For ships whose breadth is greater than 20 m, two side girders may be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks and below longitudinal bulkheads). The number of side girders to be provided may also be determined by direct calculation.

5.4.2.8 Horizontal stiffeners are to be provided at centre girders, duck keels and side girders, of which the section moment of inertia is to comply with the requirements in 5.12.2.5 of this Chapter.

5.4.2.9 Brackets extending to adjacent longitudinals are to be provided at every other frame space at both sides of centre girders between solid floors. The thickness of brackets is to be the same as that of solid floors.

5.4.2.10 The inner framing of duct keels is to comply with the following requirements:

(1) Transverse bottom frames and inner bottom frames are to be provided in way of every other frame space in duct keels, and the section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 22 s d l^2 K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;
$d$ — draft, in m;
$l$ — span, in m, taken as spacing between both side plates of duct keels;
$K$ — material factor.

(2) Both ends of transverse bottom frames and inner bottom frames are to be gradually enlarged and to be connected to side plating of duct keels, with the enlarged height being not be less than 1.5 times that of the frames. Brackets having a plate thickness equal to that of solid floors are to be provided at the corresponding position of outer side of the side plating and to be connected to the bottom and inner bottom longitudinals.

(3) Inner bottom longitudinals and bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

5.4.2.11 For oil tankers of 90 m in length and upwards, the scantlings of centre keels, duct keels and side girders are to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used.

### 5.4.3 Bottom floors

5.4.3.1 Solid floors are to be provided below lower stools of transverse bulkheads and corrugated transverse bulkheads.

5.4.3.2 The spacing of solid floors is, in general, to be not greater than (0.006$L$+3.2) in m, $L$ being length of ship.

5.4.3.3 The thickness $t$ of solid floors is not to be less than that obtained from the following formula:

$$t = (0.007 h_0 + 1.0)\sqrt{K} \quad \text{mm, but need not be greater than 14 mm}$$

where: $h_0$, $K$ — the same as that in 5.4.2.4 of this Section.

Watertight solid floors are also to comply with the requirements for deep tanks.

5.4.3.4 For oil tankers of 90 m in length and upwards, the thickness of floors is to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used. Attention is to be given to alignment of the floors when cut apart in way of girders so as to ensure the transverse continuity.

5.4.3.5 Vertical stiffeners are to be provided between bottom longitudinals and inner bottom longitudinals in way of solid floors.

### 5.4.4 Bilge brackets

5.4.4.1 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at bilge, an appropriate number of centre bilge brackets are to be provided at bilge between solid floors and connected to longitudinals at upper and lower turns of bilge. The spacing $S$ between bilge brackets and solid floors or between bilge brackets is not to be greater than that obtained from the following formula:

$$S = 8 \times 10^6 \frac{t^2}{Dr}\sqrt{\frac{t}{r}} \quad \text{mm}$$

where: $t$ — thickness of bilge strake, in mm;
$D$ — moulded depth, in m;
$r$ — radius of bilge, in mm.

The thickness of bilge brackets is to be the same as that of solid floors.

### 5.4.5 Bottom longitudinals

5.4.5.1 The maximum spacing of bottom longitudinals is not to be greater than 1 m.

5.4.5.2 The section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.5sdl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$d$ — draft, in m;
$l$ — span of longitudinal, in m;
$K$ — material factor.

5.4.5.3 Where penetrating non–watertight floors, the longitudinals are to be welded to the floors and vertical stiffeners on the floors.

Where a longitudinal is cut at watertight floors, the longitudinal is to be bracketed to the watertight floors. The size of the brackets is to comply with the requirements in 1.2.6 of this PART. For ships over 190 m in length or where higher tensile steel is adopted for longitudinals, the bottom longitudinals are to penetrate watertight floors, but an appropriate equivalent structure may be adopted as an alternative.

### 5.4.6 Inner bottom plating and inner bottom longitudinals

5.4.6.1 The thickness $t$ of inner bottom plating is not to be less than that obtained from the following formula:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: $s$ — spacing of inner bottom longitudinals, in m;
$K$ — material factor. For higher strength steels, if the material factor of lower strength level could meet the requirements of buckling check for direct strength calculation, the value $K$ of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $K$ — material factor;
$h$ — vertical distance between inner bottom plating in way of longitudinal centerline and top of the tank, in m.

5.4.6.2 Inner bottom longitudinals and the corresponding bottom longitudinals are to be in the same vertical section.

5.4.6.3 The section modulus $W$ of inner bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$, $h$ — see 5.4.6.1 of this Section;
$l$ — span of longitudinals, in m;
$K$ — material factor.

### 5.4.7 Sloping plating and slope plating longitudinals of hopper tanks

5.4.7.1 The thickness of sloping plating of hopper tanks is not to be less than those obtained from the following formula, and is not to be less than that of the adjacent inner hull plating:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: $s$ — spacing of sloping plating longitudinals, in m;
$K$ — material factor. For higher strength steels, if the material factor of lower strength level could

meet the requirements of buckling check for direct strength calculation, the value $K$ of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $K$ — material factor;
$h$ — vertical height, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline.

5.4.7.2 The section modulus of slope plating longitudinals is not to be less than that obtained from the following formula, and not to be less than that of the adjacent inner hull plating longitudinals:

$$W = 8.4s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of sloping plating longitudinals, in m;
$h$ — vertical height, in m, measured from sloping plating longitudinals to the tank top in way of longitudinal centerline;
$K$ — material factor.

# Section 5 DOUBLE HULL CONSTRUCTION

### 5.5.1 General requirements

5.5.1.1 This Section applies to the determination of arrangement and scantlings of frames in double hull within the cargo tank region of double hull oil tankers.

5.5.1.2 Manholes are to be provided in transverse bulkheads and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical to or along the length of the ship. Except for access openings, the holes on upper and lower adjacent horizontal girders are in general not to be on the same vertical line. The edge around the holes is to be strengthened.

5.5.1.3 For double hull oil tankers with the wing tanks as the ballast tanks, the inner hull structures are to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

### 5.5.2 Structural arrangement of double hull

5.5.2.1 Longitudinal continuous horizontal girders within double hull structures are to be provided at the same height as the transverse bulkhead horizontal girders of cargo tanks. A horizontal girder is to be provided at the top of the hopper tank (manhole may not be provided on the longitudinal girder for the sake of stability). The horizontal girders in wing ballast tanks, on cargo tank transverse bulkheads and on longitudinal bulkheads are to form a horizontal ring structure.

5.5.2.2 Transverse frames or transverse webs are to be provided in wing ballast tanks in line with the transverse bulkheads of cargo tanks.

5.5.2.3 Transverse frames or transverse webs are to be spaced not more than $0.006L + 3.2$ m apart and fitted in wing ballast tanks in line with double bottom transverses. Transverse frames or vertical webs, together with deck transverses of cargo tanks, vertical webs of longitudinal bulkheads, cross ties between inner hull and longitudinal bulkheads or between longitudinal bulkheads (if provided, see Figure 5.1.4.2(2)) of Section 1 of this Chapter) and double bottom transverses, are to form a transverse ring structure.

### 5.5.3 Side longitudinals

5.5.3.1 The section modulus $W$ of side longitudinals is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h+1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$h$ — vertical distance, in m, measured from longitudinals under consideration to deck at side amidships, but to be taken as not less than $0.25D$;
$l$ — span of longitudinal, in m;
$D$ — moulded depth, in m;
$K$ — material factor.

5.5.3.2 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the side longitudinals within $0.1D$ from bottom and strength deck are to penetrate continuously watertight transverse bulkheads.

Where side longitudinals are cut at watertight transverse bulkheads, they are to be bracketed to transverse bulkheads. The brackets are to have face plates and their arm length is to be increased by 20% over that required in 1.2.6 of Chapter 1 of this PART. Where the face plate is flanged, the breadth of the flange is not to be less than 8 times its thickness.

### 5.5.4 Side frames

5.5.4.1 The section modulus $W$ of side frames is not to be less than that obtained from the following formula:

$$W=7.2s\,(h+1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;
$h$ — vertical distance, in m, measured from frames under consideration to deck at side amidships, but to be taken as not less than $0.25D$;
$l$ — span of frame, in m, but not to be less than 2.5 m;
$D$ — moulded depth, in m;
$K$ — material factor.

5.5.4.2 Brackets are to be provided at both ends of side frame. The scantlings of bracket are to comply with the requirements of 1.2.6 of this PART.

### 5.5.5 Inner hull plating and its stiffeners

5.5.5.1 The inner hull plating is to extend as deep as possible at side or from top of the double bottom to the uppermost deck. The inner hull plating is to be so arranged that all cargo tanks are at the inner side of wing ballast tanks, and the inner shell is to extend as far forward and aft as practicable and effectively connected to the structures in way with adequate transition arrangements.

5.5.5.2 The thickness of inner hull plating is not to be less than that obtained from the following formula:

$$t=3.75s\sqrt{hK}+2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;
$K$ — material factor;
$D$ — moulded depth, in m.

5.5.5.3 The spacing of inner hull longitudinals is to be the same as that of side longitudinals. The section modulus $W$ of longitudinals is to comply with the requirements of 5.8.4.4, Section 8 of this Chapter.

5.5.5.4 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the inner hull longitudinals within $0.1D$ from bottom and deck are to penetrate continuously webs. Where longitudinals are cut at such webs, they are to be bracketed to the webs. The scantlings of the brackets are to comply with the requirements of 5.5.3.2 of this Section.

5.5.5.5 The section modulus $W$ of vertical stiffeners of inner hull plating is to meet the requirements of 5.8.3.3 of Section 8 of this Chapter.

5.5.5.6 Brackets are to be provided at both ends of vertical stiffeners. The scantlings of brackets are to be comply with the requirements of 1.2.6 of this PART.

### 5.5.6 Horizontal girders

5.5.6.1 The thickness $t$ of non-watertight horizontal girders within double hull structures that are provided at the same height as the transverse bulkhead horizontal girders of cargo tanks is to comply with the requirements of 5.1.5, Section 1 of this Chapter.

5.5.6.2 The scantlings of longitudinals of horizontal girders are to comply with the requirements of 5.12.2.5 of this Chapter.

5.5.6.3 On the horizontal girders, stiffeners are to be provided between side frames and vertical stiffeners of inner hull plating. The scantlings of stiffeners are to meet the requirements of 5.12.2.5 of this Chapter.

### 5.5.7 Transverse webs in double hull

5.5.7.1 Watertight transverse webs and stiffeners in double hull are to comply with the requirements for deep tanks as specified in Section 13, Chapter 2 of this PART.

5.5.7.2 Side longitudinals and inner hull longitudinals penetrating watertight transverse webs are to comply with the requirements of 5.5.3.2 and 5.5.5.4 of this Section. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

5.5.7.3 Non-watertight transverse webs supporting side longitudinals and inner hull longitudinals in double hull are to be provided in line with double bottom transverses. The thickness of non-watertight transverse webs is to comply with the requirements of 5.1.5, Section 1 of this Chapter. The side longitudinals and inner hull longitudinals are to penetrate such transverse webs. Compensation plates are to be provided at the openings to connect longitudinals and transverse structures. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

# Section 6 DECK FRAMING

### 5.6.1 General requirements

5.6.1.1 This Section applies to arrangement method and scantling determination of longitudinal deck framing within cargo oil tanks of double hull oil tankers.

### 5.6.2 Deck transverses

5.6.2.1 Deck transverses are to be fitted in every plane of the bottom transverses.

5.6.2.2 The section modulus $W$ of deck transverses is not to be less than that obtained from the following formula:

$$W = CLS(l + 1)K \quad \text{cm}^3$$

where: $C$ — coefficient, $C$ = 1.80 for centre oil tanks, $C$ = 1.92 for wing oil tanks;

$S$ — spacing of deck transverses, in m;

$L$ — length of ship, in m, to be taken as not less than 65 m, but need not be more than 190 m;

$l$ — span of deck transverse, in m;

$K$ — material factor.

5.6.2.3 The section moment of inertia $I$ of the deck transverse is not to be less than that obtained from the following formula:

$$I = 7.5Wl/K \quad \text{cm}^4$$

where: $W$, $l$ and $K$ — as defined in 5.6.2.2 of this Section.

In addition, the web depth of deck transverses mentioned above is not to be less than 2.5 times the depth of the cut-outs for the passage of deck longitudinals.

5.6.2.4 Stiffeners normal to the face plate are to be fitted on the web plate of deck transverses at alternate longitudinals. Where the web depth of deck transverses exceeds $210t\sqrt{K}$ ($t$ being the thickness of the web plate and $K$ being material factor), an additional horizontal stiffener is to be fitted at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets, spaced not more than 4.5 m or 20 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of deck transverses and elsewhere. The tripping brackets is to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.6.2.5 Deck transverses are to be connected by end brackets to inner hull plating, longitudinal bulkheads, side framing and continuous deck girders. The scantlings of the brackets are to comply with the requirements of 1.2.7 of this PART. Where connected to continuous deck girders, the brackets are to extend to the face plate of girders and to be welded to it.

### 5.6.3 Deck girders

5.6.3.1 The section modulus $W$ of the continuous deck girders is not to be less than that obtained from the following formula:

$$W = 0.1Lbl^2K \quad \text{cm}^3$$

where: $L$ — length of ship, in m;

$b$ — mean width of load-bearing area of the continuous deck girders, in m;

$l$ — span of the continuous deck girder, in m;

$K$ — material factor.

5.6.3.2 Where the web height of continuous deck girders are greater than $65t\sqrt{K}$ (where $t$ is web thickness, $K$ is material factor), they are to be stiffened parallel to the girder face plate. The stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets are to be fitted to the continuous deck girders in accordance with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.6.3.3 The connection of deck girders to transverse bulkheads or to the vertical webs on transverse bulkheads is to comply with the requirements of 1.2.7, Chapter 1 of this PART.

### 5.6.4 Deck longitudinals

5.6.4.1 The section modulus $W$ of deck longitudinals is not to be less than that obtained from the following formula:

$$W = csl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$l$ — span of longitudinal, in m, but not to be less than 2.5 m;

$c$ — coefficient, to be taken as the greater of the following values: $c = 0.35L$ or $c = 0.12L + 12.6$, where $L$ being the length of ship, in m; for $L > 190$ m, to be taken as 190 m;

$K$ — material factor.

5.6.4.2 Deck longitudinals, in association with the deck plating, may be gradually tapered outside $0.4L$ amidships towards the ends. At $0.075L$ from ends, the section modulus of deck longitudinals is not to be less than 80% of the value obtained from 5.6.4.1 of this Section and in addition, not to be less than that required in 2.8.5.1, Chapter 2 of this PART for deck longitudinals at the ends of ships.

5.6.4.3 Connections of deck longitudinals to transverse bulkheads are to provide adequate fixity and continuity of longitudinal strength. For ships over 150 m in length or where higher tensile steel is adopted for deck longitudinals, the longitudinals are to be continuous through the transverse bulkheads.

Where the deck longitudinals are cut in way of the transverse bulkheads, they are to be bracketed to the bulkheads, and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. Where flanged face plates are used for the brackets, the breadth of the flange is not to be less than 8 times its thickness.

Deck longitudinals are to be welded to the web of deck transverses, and to be welded to the stiffeners of deck transverses when intersecting the stiffeners.

# Section 7 PLANE TRANSVERSE OILTIGHT BULKHEADS

### 5.7.1 General requirements

5.7.1.1 The stiffening on the plane transverse bulkheads, in general, may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs.

5.7.1.2 Horizontal girders of transverse bulkheads are to be fitted in line with the horizontal girders in double hull and with horizontal girders of longitudinal bulkheads. The vertical stiffeners are to be fitted on the same longitudinal section as bottom and inner bottom longitudinals.

5.7.1.3 Vertical webs, if fitted, are to be fitted on the same longitudinal section as deck girders and bottom girders. The horizontal stiffeners are to be fitted at the same level as side longitudinals and inner hull longitudinals.

### 5.7.2 Thickness of bulkhead plating

5.7.2.1 The thickness $t$ of the bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;

$K$ — material factor.

5.7.2.2 The thickness $t$ of the bulkhead plating is to comply with the following requirements:

(1) Where horizontal girders and vertical stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{60\sqrt{K}} \quad \text{mm, for the lower 1/4 of the bulkhead}$$

(2) Where vertical webs and horizontal stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{85\sqrt{K}} \quad \text{mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm, for the lower 1/4 of the bulkhead}$$

where: $s$ — spacing of stiffeners, in m;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

### 5.7.3 Horizontal girders and vertical stiffeners

5.7.3.1 The section modulus $W$ of horizontal girders is not to be less than that obtained from the following formula:

$$W = 10.5b\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $b$ — width of plating supported by the girder, i.e. half the sum of the lengths of the intersected vertical stiffener above and below the horizontal girder, in m;

$h$ — vertical distance, in m, measured from horizontal girder to the tank top in way of longitudinal centreline;

$l$ — span of horizontal girder, in m;

$K$ — material factor.

The web depth of the horizontal girder is not to be less than 2.5 times the depth of the cut-outs for the passage of vertical stiffeners.

5.7.3.2 Where the horizontal girders together with the horizontal girders on longitudinal bulkheads and the horizontal girders in double hull do not form a ring structure, the brackets at both ends of the horizontal girders are to extend to the adjacent vertical web or webs. The thickness of the brackets is to be the same as the web thickness of the horizontal girders, and the face plate of the brackets is to be the same as that of the horizontal girders.

5.7.3.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of horizontal girders. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

5.7.3.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of horizontal girders and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.7.3.5 The web thickness of horizontal girders is not to be less than $s/80$ ($s$ being the spacing of stiffeners, in m). Stiffeners normal to the face plate are to be fitted on one side of every vertical stiffener on the web plate of horizontal girders. Where the web depth of horizontal girders exceeds $165t\sqrt{K}$ ($t$ being the thickness of the web plate and $K$ being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate.

5.7.3.6 Where continuous deck girders are fitted in way of the longitudinal centreline on deck, a vertical centreline web is also to be fitted. The scantlings are to be determined by direct calculation. The connection between them is to comply with the requirement of 1.2.7 of this PART.

5.7.3.7 The section modulus $W$ of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from mid- span of stiffeners to the tank top in way of longitudinal centerline, but to be taken as not less than $0.25D$;

$l$ — span of stiffener, in m;

$K$ — material factor.

5.7.3.8 The stiffeners are to be connected to the inner bottom and deck longitudinals by brackets at both ends. The brackets are to comply with the requirements of 1.2.6 of this PART. The stiffeners are to be welded to the web of horizontal girders and vertical stiffeners on the web when penetrating horizontal girders.

### 5.7.4 Vertical webs and horizontal stiffeners

5.7.4.1 The section modulus $W$ of vertical webs is not to be less than that obtained from the following formula:

$$W = Cb\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $b$ — width of plating supported by the vertical web, i.e. half the total length of the horizontal stiffener intersecting the vertical web, in m;

$h$ — vertical distance, in m, measured from mid- span of the vertical web to the tank top in way of longitudinal centreline;

$l$ — span of vertical web, in m;

$C$ — coefficients: $C = 11$, for the vertical web at the centreline; $C = 8.8$, for the vertical web not on the centreline but supporting the horizontal stiffeners;

$K$ — material factor.

The web depth of vertical webs is not to be less than 2.5 times the depth of the cut-outs for the passage of horizontal stiffeners.

5.7.4.2 Where vertical webs, bottom girders and deck girders do not form a ring structure, the brackets at both ends of the vertical web are to extend to the adjacent deck transverse or bottom transverse. The

thickness of the brackets is to be the same as the web thickness of the vertical webs, and the face plate of the brackets is to be the same as that of the vertical webs, or an alternative effective structural configuration is to be adopted to ensure the continuity of the structure.

5.7.4.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of the vertical webs. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

5.7.4.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of vertical webs and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.7.4.5 Vertical webs are to be fitted with stiffeners parallel to the girder face plate and spaced not more than 60 $\sqrt{K}$ ($K$ being material factor) times the web thickness apart. When horizontal stiffeners on transverse bulkheads are supported by vertical girders, stiffeners normal to the face plate are to be fitted at every horizontal stiffener. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

5.7.4.6 The section modulus $W$ of horizontal stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the stiffener to the tank top in way of longitudinal centreline, but not to be less than $0.25D$, in m;

$l$ — span of stiffener, in m;

$K$ — material factor.

5.7.4.7 The stiffeners are to be connected to the inner hull and the horizontal stiffeners of longitudinal bulkheads by brackets having the scantlings as required in 1.2.6, Chapter 1 of this PART. Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

# Section 8 PLANE LONGITUDINAL OILTIGHT BULKHEADS

### 5.8.1 General requirements

5.8.1.1 Longitudinal bulkheads are to be continuous throughout all cargo tanks, and are to extend as far forward and aft as possible. Where the longitudinal bulkheads are cut, large brackets or other longitudinal transitional members are to be fitted to ensure effective continuity.

5.8.1.2 The stiffening on the longitudinal bulkheads may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs. Horizontal girders are to be fitted at the same level as those of transverse bulkheads, and vertical stiffeners are to be fitted on the transverse section of transverse frames. Vertical webs are to be fitted on the same transverse section as bottom floors, and horizontal stiffeners are to be fitted at the same level as side longitudinals.

5.8.1.3 Continuous girders are to be fitted in double bottom at plane longitudinal bulkheads.

### 5.8.2 Thickness of bulkhead plating

5.8.2.1 The thickness $t$ of the longitudinal bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the lower edge of strake to the tank top in way of longitudinal centreline; but not less than $0.4D$, in m;

$K$ — material factor;

$D$ — moulded depth of ship, in m.

5.8.2.2 The thickness of the longitudinal bulkhead plating within $0.1D$ from deck need not exceed the sheer strake thickness with the same frame spacing.

### 5.8.3 Horizontal girders and vertical stiffeners

5.8.3.1 The section modulus of horizontal girders is to be calculated in accordance with 5.7.3.1 of this Chapter and to comply with relevant requirements, but the span under consideration is not to be less than 3 m.

5.8.3.2 Horizontal girders and those of transverse bulkheads are to be connected as required in 1.2.7 of this PART.

5.8.3.3 The section modulus $W$ of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$, $h$, $l$ and $K$ are the same as that in 5.7.3.7 of this Chapter.

5.8.3.4 Stiffeners are to be bracketed at both ends. These brackets are to extend to the nearest inner bottom and deck longitudinals and the scantlings of these brackets are to comply with the requirements of 1.2.6 of this PART, but the depth of the lower bracket along the stiffener is not to be less than 15% of the distance between the ship's bottom and the adjacent horizontal girder. Vertical stiffeners are to be welded to the web plate and stiffeners of the horizontal girders.

### 5.8.4 Vertical webs and horizontal stiffeners

5.8.4.1 Where one longitudinal bulkhead is fitted, vertical webs symmetrical to the longitudinal centerline are to be fitted in line with floors. The vertical webs may also to be fitted at one side of the longitudinal bulkhead. Where two longitudinal bulkheads are fitted, vertical webs are to be fitted in compartments with cross ties.

5.8.4.2 The section modulus of vertical webs is not to be less than that obtained from the following formula:

$$W = CS\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $S$ — spacing of vertical webs, in m;

$h$ — vertical distance, in m, measured from the mid-span of vertical webs to tank top;

$l$ — span of vertical webs, in m;

$C$ — coefficient: $C$ = 11, without horizontal cross tie; $C$ = 3.2, with 1 horizontal cross tie; $C$ = 3, with 2 horizontal cross ties;

$K$ — material factor.

5.8.4.3 The end brackets of vertical webs are to comply with the requirements of 1.2.7, Chapter 1 of this PART.

5.8.4.4 The section modulus $W$ of horizontal stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from stiffeners to tank top at longitudinal centerline, but not less than 0.25$D$;

$l$ — span of stiffener, in m;

$K$ — material factor.

5.8.4.5 For ships over 150 m in length or where higher tensile steel is adopted, the horizontal stiffeners on longitudinal bulkheads within 0.1$D$ from bottom and deck are to be continuous through transverse bulkheads. Where the horizontal stiffeners are cut at the transverse bulkheads, they are to be bracketed to the transverse bulkheads. Where the transverse bulkheads are stiffened vertically, the brackets at the ends of horizontal stiffeners are to extend to the nearest vertical stiffeners of the transverse bulkheads; the scantlings of the brackets are to be in accordance with the requirements of 5.5.3.2 of this Chapter.

Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

### 5.8.5 Cross ties

5.8.5.1 In oil tankers having two longitudinal bulkheads, horizontal cross ties are to be arranged in the transverse ring structure as shown in Figure 5.1.4.2(2). The cross ties are to be located as follows: where one horizontal cross tie is arranged, the centerline of the cross tie is to be between 0.5$D$ and 0.7$D$ from deck; where two horizontal cross ties are arranged, the centerline of the upper one is to be between 0.4$D$ and 0.5$D$ from deck, while the centerline of the lower one is to be between 0.7$D$ and 0.8$D$ from deck. Cross ties may be omitted in transverse ring structures adjacent to watertight transverse bulkheads.

5.8.5.2 The sectional area $A$ and section moment of inertia $I$ of the horizontal cross ties are not to be less than those obtained from the following formulae:

$$A = 1.1Kbs(h + 1.2) + 50K \quad \text{cm}^2$$

$$I = 2.1bs\,(h + 1.2)\,l^2 \quad \text{cm}^4$$

where: $b$ — width of plating supported, in m, taken as half of the moulded depth when one cross tie is arranged or half the distance from deck or bottom to the adjacent cross tie when two cross ties are arranged;

$h$ — vertical distance, in m, measured from the centerline of the cross tie to deck at side;

$s$ — spacing of transverse ring structures, in m;

$K$ — material factor;
$l$ — length of cross ties, in m.

5.8.5.3 Substantial vertical and horizontal brackets are to be fitted at ends of cross ties for connection of cross ties to the vertical webs of inner hull and longitudinal bulkheads. The vertical brackets are to be in line with the cross tie web plates, and the horizontal brackets are to be in line with the cross tie face plates.

5.8.5.4 Stiffeners parallel to the face plate are to be fitted on the web plate of cross ties. Where $L \leq 90$ m, the distance between the stiffener and the face plate or between two stiffeners is not to exceed $80\,t\sqrt{K}$ ($t$ being the thickness of cross tie webs, $K$ being material factor); where $L \geq 190$ m. the distance is not to exceed $55\,t\sqrt{K}$ . Intermediate values are to be obtained by interpolation.

Brackets are to be fitted on the web plate of cross ties to support the face plate and horizontal stiffeners.

5.8.5.5 Cross ties are to be subject to buckling check.

# Section 9 CORRUGATED TRANSVERSE OILTIGHT BULKHEADS

### 5.9.1 General requirements

5.9.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

5.9.1.2 Vertical corrugations are generally to be adopted for corrugated transverse bulkheads except in special cases. The angle between flange and web portions of the corrugation is not to be less than 40º.

5.9.1.3 For oil tankers of 190 m or over in length, lower stools and in general, upper stools are to be provided for vertical corrugated bulkheads.

### 5.9.2 Corrugation dimensions and bulkhead plating

5.9.2.1 The thickness of transverse corrugated bulkheads is to be determined according to 5.7.2.1 of this Chapter. In calculation, $s$ is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm}$$

where: $s$ — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;
$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

5.9.2.2 The section modulus $W$ and moment of inertia $I$ of a corrugation of bulkheads are not to be less than those obtained from following formulae respectively:

$$W = 8.8s\,(h + 1.2)\,l^2K \text{ cm}^3$$
$$I = 3.2Wl/K \text{ cm}^4$$

where: $s$ — breadth of a corrugation, in m;
$h$ — vertical distance, in m, measured from the mid- span of the corrugation to the tank top in way of longitudinal centerline;
$l$ — span of corrugation, in m;
$K$ — material factor.

### 5.9.3 Lower stools

5.9.3.1 Lower stools are to comply with the requirements of 8.4.1 of this PART.

5.9.3.2 Where the spacing of longitudinal girders in double bottom under the lower stool is greater than 3.8 m, local girders are to be provided. Longitudinal webs are to be provided at center girders, side girders and local girders in the lower stool.

### 5.9.4 Upper stools

5.9.4.1 Upper stools are to comply with the requirements of 8.4.1 of this PART.

### 5.9.5 Arrangement of structure with no lower stool or upper stool

5.9.5.1 At deck, if no stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

5.9.5.2 At bottom, if no stool is fitted, corrugated bulkhead plating is to be connected to the inner bottom plating by full penetration welds. The plating of supporting floors is to be connected to the inner bottom by

either full penetration or deep penetration welds. The thickness and material properties of the supporting floors are to be at least equal to those provided for the corrugation flanges. Moreover, the cutouts for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by shear plates.

5.9.5.3 Stool side plating is to align with the corrugation flanges and stool side vertical stiffeners and the brackets in lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. Stool side plating is not to be knuckled anywhere between the bottom plating and the stool top.

### 5.9.6 Horizontal girders

5.9.6.1 Where horizontal girders are provided for corrugated transverse bulkheads, the scantlings and structures of the horizontal girders are to comply with the requirements for plane bulkhead horizontal girders specified in 5.7.3 of this Chapter.

5.9.6.2 The considered depth of the web of horizontal girders is to be taken as the minimum distance between the face plate and the bulkhead.

## Section 10 CORRUGATED LONGITUDINAL OILTIGHT BULKHEADS

### 5.10.1 General requirements

5.10.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

5.10.1.2 The angle between web and flange of the corrugation is generally not to be less than 40º.

5.10.1.3 Corrugated longitudinal bulkheads are not recommended for oil tankers of 190 m or over in length.

5.10.1.4 Corrugated longitudinal bulkheads may be horizontally or vertically corrugated. Any arrangement, with both longitudinal and transverse bulkheads being horizontally corrugated, is to be avoided.

### 5.10.2 Vertically corrugated longitudinal bulkheads

5.10.2.1 The thickness of plating of corrugated longitudinal bulkheads is to comply with the requirements of 5.8.2.1 of this Chapter. In calculation, $s$ is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm}$$

where: $s$ — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;

$K$ — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of $K$ for a lower strength level may be taken.

5.10.2.2 The section modulus $W$ and moment of inertia $I$ of a corrugation of bulkheads are not to be less than those obtained from following formulae:

$$W = 8.8s\,(h + 1.2)\,l^2K \text{ cm}^3$$

$$I = 3.2Wl/K \quad \text{cm}^4$$

where: $s$ — breadth of a corrugation, in m;

$h$ — vertical distance, in m, measured from the mid- span of the corrugation to the tank top in way of longitudinal centerline; $h$ is not to be less than 2.5 m;

$l$ — span of corrugation, in m;

$K$ — material factor.

5.10.2.3 Upper stools and lower stools are generally to be fitted at vertically corrugated longitudinal oiltight bulkheads.

5.10.2.4 The height of the lower stools is generally not to be less than 3 times the depth of the corrugations. The thickness and material grade of the stool top plate are not to be less than those required for the bulkhead plating above. The thickness and material grade of the upper portion of vertical or sloping stool side plating, within the depth equal to the corrugation flange width from the stool top, are not to be less than the flange plate thickness and material grade needed to meet the bulkhead stiffness requirements at the lower end of the corrugation.

The distance from the edge of the stool top plate to the surface of the corrugation flange is not to be less

than 1.5 times the corrugation flange plate thickness. The stool bottom is to be fitted in line with duct keels in double bottoms and is to have a width not less than 2.5 times the mean depth of the corrugation.
Vertical stiffeners are to be fitted on the lower stool side plating in line with the frames mentioned in 5.4.2.10 of this Chapter. Both ends of the stiffeners are to be bracketed to upper and lower ends of the stool.
Horizontal stiffeners, of which the moment of inertia $I$ may be determined according to 5.12.2.5(2) of this Chapter, are also to be fitted on the lower stool side plating. Diaphragms, the thickness of which is to be the same as that of double bottom solid floors, are to be fitted inside the lower stool in line with solid floors.
Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.
5.10.2.5 The upper stool is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of corrugations, but greater than the height of deck transverses. The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than 2 times the depth of corrugations. The side plating of the upper stool may be connected directly to the deck, and to be bracketed transversely to beams.
The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. Where vertical stiffeners are fitted at side plating of the upper stool, both ends of the stiffeners are to be bracketed to the upper and lower ends of the stool.
Horizontal stiffeners are also to be fitted at side plating of the upper stool. Diaphragms, the thickness of which is to be the same as that of the web of deck transverses, are to be fitted inside the stool in line with deck transverses.
Scallops in the brackets and diaphragms in way of the connection to the stool top plate are to be avoided.
5.10.2.6 If no bottom stool is fitted, the corrugation flanges are to be in line with the side plating of duct keels and connected to the inner bottom plating by full penetration welds.
5.10.2.7 Where horizontal girders are fitted, they are to comply with the requirements of 5.9.6.

### 5.10.3 Horizontally corrugated longitudinal bulkheads

5.10.3.1 The thickness of plating of horizontally corrugated longitudinal bulkheads is to comply with the requirements of 5.8.2.1 of this Chapter. In calculation, $s$ is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater.
5.10.3.2 The section modulus of a corrugation of the bulkhead is to be determined according to 5.10.2.2 of this Chapter.
5.10.3.3 The flat bottom of horizontally corrugated bulkheads is to be in line with longitudinal girders in double bottom and connected to the inner bottom plating by full penetration welds. The top is welded directly to deck. Both the width of bottom and top flat portion are not to be less than $0.1D$ for ships of more than 150 m in length.
5.10.3.4 Where the width of the flat bottom and top is greater than that of corrugation flange or web, an appropriate stiffening structure is to provided.
5.10.3.5 Vertical webs of horizontally corrugated bulkheads are to be fitted in line with solid floors, and are to comply with the requirements of 5.8.4 of this Chapter. The web depth of the vertical webs is to be taken as the minimum distance between the face plate of vertical webs and the bulkhead.

## Section 11 NON-OILTIGHT BULKHEADS AND WASH BULKHEADS

### 5.11.1 General requirements

5.11.1.1 Where transverse non-oiltight or wash bulkheads are fitted in the cargo tanks, they are to have an area of perforations not less than 10% of the total area of the bulkhead, and the area of perforations is not to be more than 25% of the total area of the bulkhead for longitudinal non-oiltight bulkheads.
5.11.1.2 Where non-oiltight bulkheads support the bottom centre girder, the perforations are to be so arranged as not to impair the efficiency of the bulkhead as a support to the hull structure. Essential openings (such as openings for pipes, access, etc.) in the lower portion of bulkheads are to be circular with edge stiffening.
5.11.1.3 Non-oiltight or wash bulkheads are to be provided with access openings not less than 600 mm × 800 mm in size.

### 5.11.2 Bulkhead plating and stiffening

5.11.2.1 The thickness of bulkhead plating is not to be less than that required in 5.1.5 of this Chapter. The thickness of the transverse bulkhead plating supporting centre girders, in addition, is to meet the

requirements of 5.7.2.2 of this Chapter and in no case are the panel dimensions to exceed 180 times the thickness of the bulkhead plating.

5.11.2.2 The net vertical sectional area $A$ of the non-oiltight transverse bulkhead supporting centre girders is not to be less than that obtained from the following formula:

$$A = 0.14 l_x b D_x K \quad \text{cm}^2$$

where: $l_x$ — the distance, in m, between the bulkheads (oiltight or non-oiltight) adjacent to the non-oiltight bulkhead under consideration;

$b$ — overall breadth of oil tank, in m;

$D_x$ — actual depth of non-oiltight transverse bulkheads or transverse wash bulkheads, in m;

$K$ — material factor.

5.11.2.3 The section modulus $W$ of stiffeners is not to be less than that obtained from the following formula:

$$W = 125 s l^2 K \frac{l_x}{L} \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m;

$K$ — material factor;

$l_x$ — see 5.11.2.2 of this Section;

$L$ — length of ship, in m.

5.11.2.4 Stiffeners are to be bracketed at their ends. The scantlings of the brackets are to comply with the requirements of 1.2.6 of this PART.

### 5.11.3 Vertical webs and horizontal girders

5.11.3.1 Horizontal girders, vertical webs or stiffeners are to be fitted on the non-oiltight or wash bulkheads in line with the strength members which are supported by the bulkheads.

5.11.3.2 The section modulus of vertical webs is not to be less than one half of that required for the vertical webs of oiltight bulkheads arranged in the same way.

5.11.3.3 The section modulus $W$ of horizontal girders is not to be less than that obtained from the following formula:

$$W = 150 b l^2 K \frac{l_x}{L} \quad \text{cm}^3$$

where: $b$ — width of plating supported by the girder, in m, i.e. half the sum of the lengths of the intersected stiffener above and below the girder, in m;

$l$ — span of girder, in m;

$K$ — material factor;

$l_x$ — see 5.11.2.2 of this Section;

$L$ — length of ship, in m.

## Section 12 SPECIAL REQUIREMENTS

### 5.12.1 General requirements

5.12.1.1 The symmetrical section is to be adopted as far as applicable for side longitudinals and inner hull longitudinals between 2 m below the ballast waterline and 2 m above the full-loaded waterline. The symmetrical section is also recommended for longitudinals within the above-mentioned extent of longitudinal bulkheads to avoid additional torsional stress. Where higher tensile steel is adopted for side longitudinals and vertical stiffeners or brackets on primary transverse structural webs are connected directly to side longitudinals, the toes of stiffeners or brackets within the above-mentioned extent are to be well radiused (see Figure 5.12.1.1). Where appropriate fatigue assessment is provided, other structural arrangements will be considered.

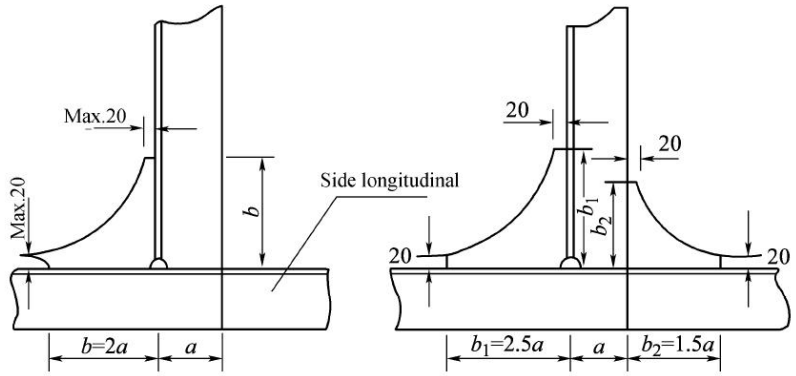
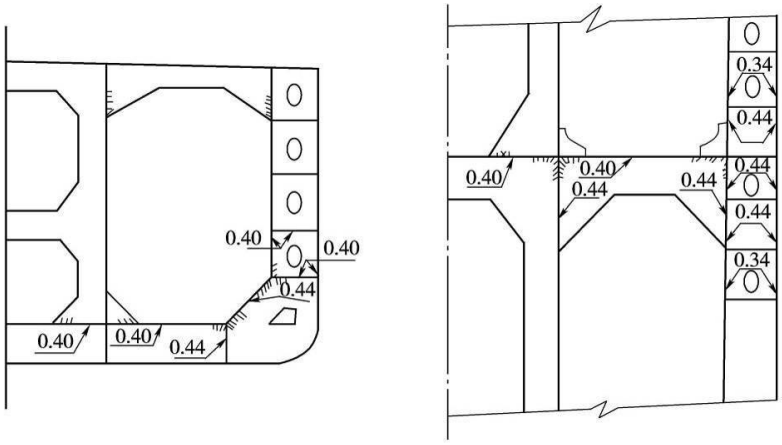



**Figure 5.12.1.1**

5.12.1.2 Where side longitudinals of higher tensile steel pass through watertight transverse bulkheads in the cargo tank region, radiused brackets of the same material are to be fitted on both the fore and aft sides of the connection between the upper edge of bilge and 0.8*D* above the draft line, and attention is to be given to ensure the alignment of the brackets.

5.12.1.3 For oil tankers greater than 250 m in length, special attention is to be given to the alignment for connection of the transverse ring system and transverse bulkhead horizontal girders as shown in Figure 5.12.1.3 to relevant adjacent members and to the application of full penetration or increased throat thickness for fillet welds. The length of the increased throat thickness is not to be less than 2*s* or 1.2 m, whichever is the greater, where *s* is spacing of secondary members, in m.




Note: Deep penetration welds are required for shadow areas, and increased throat thickness based on weld factors as shown in the Figure is required for other areas.

**Figure 5.12.1.3**

### 5.12.2 Structure details

5.12.2.1 Where flat steel is adopted for longitudinals, the ratio of height to thickness is not to be greater than 18 $\sqrt{K}$ (*K* being material factor) for the longitudinals penetrating bulkheads and not greater than 15 $\sqrt{K}$ for the longitudinals cut at bulkheads. Where flat steel is adopted for stiffeners, the ratio of height to thickness is not to be greater than 18 $\sqrt{K}$ .

5.12.2.2

(1) The diameter of lightening holes of primary members is not to be greater than 20% of the web height. The distance between the edge of the hole and face plate is not to be less than 40% of the web height, and an equal distance is in general to be kept from the edge of the hole to the corner of notches for the passage of frames. The holes are to be kept clear of notches and bracket toes. The edge of holes are to be well rounded with smooth edges.

(2) Openings with a diameter larger than that specified above are subject to check by direct calculation according to the requirements in Appendix 1 of this Chapter.

(3) Lightening holes are not to be provided on webs of primary members (e.g. side girders, longitudinal bulkhead horizontal girders) in way of cross ties and their end connections.

5.12.2.3 The holes on webs of primary longitudinal members within 0.1*D* (*D* being moulded depth) from deck and bottom are generally to be strengthened. Access holes on deep longitudinal and transverse girders

are to be provided with suitable compensation, so as to satisfy the requirement for resistance to local deformation and shear buckling in the web.

5.12.2.4 The lower edge of holes cut for oil heating piping is not to be less than 100 mm from the shell plating; where notches are cut for the passage of longitudinals, adjacent to such holes, the notches are to be collared.

5.12.2.5 The web depth of stiffeners of primary members is not to be less than 75 mm. Where stiffeners are to be provided both parallel and vertical to the face plate, the scantlings of stiffeners parallel to the face plate are not to be less than those of stiffeners vertical to the face plate. The section moment of inertia of stiffeners is to comply with the following requirements respectively:

(1) The section moment of inertia $I$ of stiffeners vertical to the face plate of primary members is not to be less than that obtained from the following formula:

$$I = 0.175\left(\frac{h}{s}\right)^{2.4} st^3 \quad \text{cm}^4$$

where: $h$ — spacing of horizontal stiffeners for main structural member, or depth of web without stiffeners, in m;

$s$ — spacing of stiffeners, in m;

$t$ — thickness of web, in mm.

In calculation, 1 is to be taken for $h/s < 1$ and 3.3 for $h/s > 3.3$.

(2) The section moment of inertia $I$ of stiffeners parallel to the face plate of primary members is not to be less than that obtained from the following formula:

For longitudinal stiffeners:

$$I = 1.62l^2 A \quad \text{cm}^4$$

For other stiffeners:

$$I = 0.82l^2 A \quad \text{cm}^4$$

where: $l$ — spacing of stiffeners, in m;

$A$ — sectional area of stiffeners with attached plates, in cm².

5.12.2.6 Stiffeners are to be provided for large brackets so that the side length of the non-stiffened triangle of the bracket is not greater than 100 times the thickness of the bracket. Stiffeners are to be parallel to the face plate. The distance from the stiffeners near the face plate to the face plate is not to be greater than 30 times the thickness of the bracket. The spacing of other stiffeners may not be greater than 45 times the thickness of bracket plating. The face plate and stiffeners are to be appropriately supported against tripping. Where the face plate is non-continuous at the structural member, both ends of the face plate are to be sniped.

5.12.2.7 The height of bracket stiffeners is not to be less than 75 mm, and their section moment of inertia $I$ is specified as follows:

For the brackets of deck stringers and keel, not to be less than:

$$I = 3l^2 A \quad \text{cm}^4$$

For those of other primary members, not to be less than:

$$I = 2l^2 A \quad \text{cm}^4$$

where: $l$ — span of stiffeners, in m;

$A$ — sectional area of stiffeners with attached plates, in cm².

5.12.2.8 In the cargo tank region, integral brackets with continuous face plates are to be adopted as far as practicable for end brackets of primary members. Where the thicknesses of face plates connecting two primary members are different, the primary member with the larger face plate is to have the width of its face plate being maintained to the mid-point of the free side of the bracket and gradually tapered to the smaller face plate of the other primary member. The taper is generally not to exceed 1:3 and where the width of the face plate is greater than 500 mm, the taper is not to exceed 1:4. Where a thick face plate is connected to a thinner one, the difference in thickness is not to exceed 4 mm and in the event that the difference exceeds 4 mm, the taper on thickness is to be 1:3.

# Section 13 CARGO TANK HATCHWAYS

### 5.13.1 General requirements

5.13.1.1 Cargo tank hatchways and ladders are to be fitted in compliance with Section 8, Chapter 1 of this PART.

### 5.13.2 Requirements for cargo tank hatchways

5.13.2.1 The height of the hatch coaming is not to be less than 600 mm, and the thickness of the coaming plating is not to be less than 10 mm. Where the height of coaming exceeds 600 mm, the coaming is to be increased in thickness and reinforced by horizontal stiffeners on the upper portion.

5.13.2.2 The thickness of hatch covers is not to be less than 12 mm. Where the area of the cover exceeds 1.2 $m^2$, the cover is to be reinforced by stiffeners or increased in thickness.

5.13.2.3 Hatch covers are to be secured by bolts spaced generally not more than 460 mm apart, and not more than 230 mm from hatch corners.

5.13.2.4 Sighting ports having a diameter not less than 150 mm are to be provided in the covers. These holes are to be provided with effective closing appliances to ensure oil-tightness.

# Appendix 1 DIRECT STRENGTH CALCULATION OF DOUBLE HULL OIL TANKERS

## 1 GENERAL

### 1.1 Application

1.1.1 This Appendix applies to direct calculations, required by this Chapter, of the structural strength of double hull oil tankers.

1.1.2 Where not stipulated in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

1.1.3 For partially filled cargo tanks, consideration is to be given to the sloshing strength under the sloshing pressure due to liquid motion.

## 2 DESIGN LOADS

### 2.1 General requirements

2.1.1 Unless stipulated otherwise in the Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless stipulated otherwise in the Appendix, the still water bending moment in the global load condition is to be taken as the allowable value $\overline{M}_s$ provided by the designer; the wave bending moment $M_w$ is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_{sp}$ is determined by the designer, but is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual.

## 3 LOADING CONDITIONS

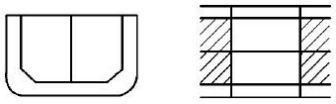
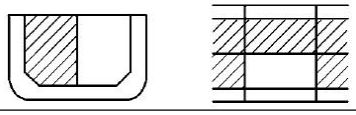
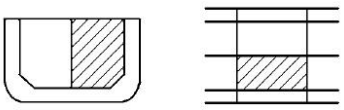
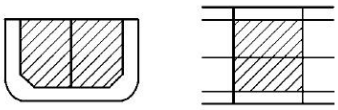
### 3.1 General requirements

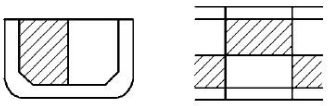
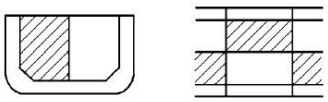
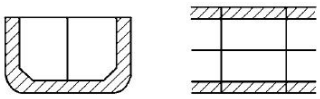
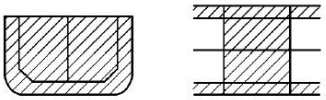
3.1.1 Normally, the corresponding loading conditions are to be selected from Tables 3.2.1 to 3.2.3 of this Appendix for check. For other more severe loading conditions in the loading manual which are not covered by these Tables, direct strength calculation is also to be carried out.

### 3.2 Loading conditions

3.2.1 The loading conditions of oil tankers with one longitudinal bulkhead are referred to in Table 3.2.1. For the conditions of LC2, LC3, LC5, LC6, if the structures are not symmetrical to the longitudinal centreline, the loading conditions of tanks on starboard and port sides are to be included respectively.

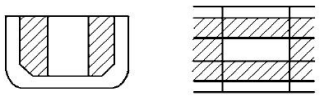
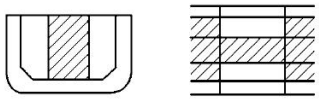
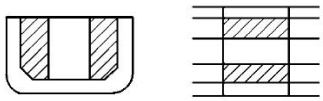
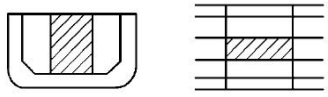
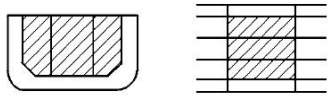
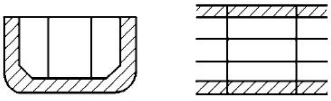
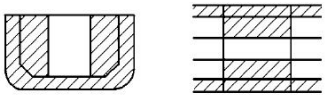
**Loading Conditions** **Table 3.2.1**

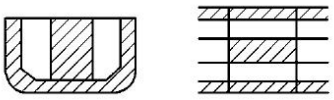
| Loading condition | Draught | Still water bending moment | Wave bending moment | Mode of loading |
|---|---|---|---|---|
| LC1 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC2 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC3 | $0.35D$ | $\overline{M}_{sp}$ | – |  |
| LC4 | $0.35D$ | $\overline{M}_{sp}$ | – |  |

| Loading condition | Draught | Still water bending moment | Wave bending moment | Mode of loading |
|---|---|---|---|---|
| LC5 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC6 | 0.25$D$ | $\overline{M}_{sp}$ | – |  |
| LC7 | Ballast draught | $\overline{M}_s$ | $M_w$ |  |
| LC8 | Heavy ballast draught | $\overline{M}_s$ | $M_w$ |  |

3.2.2 For oil tankers with two longitudinal bulkheads, loading conditions are referred to in Table 3.2.2.

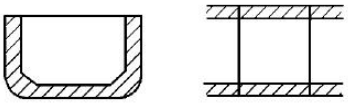
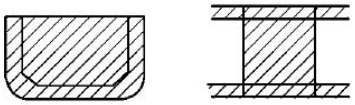
**Loading Conditions** **Table 3.2.2**

| Loading condition | Draught | Still water bending moment | Wave bending moment | Mode of loading |
|---|---|---|---|---|
| LC1 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC2 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC3 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC4 | 0.25$D$ | $\overline{M}_{sp}$ | – |  |
| LC5 | 0.25$D$ | $\overline{M}_{sp}$ | – |  |
| LC6 | 0.35$D$ | $\overline{M}_{sp}$ | – |  |
| LC7 | 0.35$D$ | $\overline{M}_{sp}$ | – |  |
| LC8 | Ballast draught | $\overline{M}_s$ | $M_w$ |  |
| LC9 | Heavy ballast draught | $\overline{M}_s$ | $M_w$ |  |

| Loading condition | Draught | Still water bending moment | Wave bending moment | Mode of loading |
|---|---|---|---|---|
| LC10 | Heavy ballast draught | $\overline{M}_s$ | $M_w$ |  |

3.2.3 For oil tankers without longitudinal bulkheads, loading conditions are referred to in Table 3.2.3.

**Loading Conditions** **Table 3.2.3**

| Loading condition | Draught | Still water bending moment | Wave bending moment | Mode of loading |
|---|---|---|---|---|
| LC1 | $d$ | $\overline{M}_s$ | $M_w$ |  |
| LC2 | 0.35$D$ | $\overline{M}_{sp}$ | – |  |
| LC3 | Ballast draught | $\overline{M}_s$ | $M_w$ |  |
| LC4 | Heavy ballast draught | $\overline{M}_s$ | $M_w$ |  |

## 4 STRUCTURAL MODELING

### 4.1 General requirements

4.1.1 Unless stipulated otherwise in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

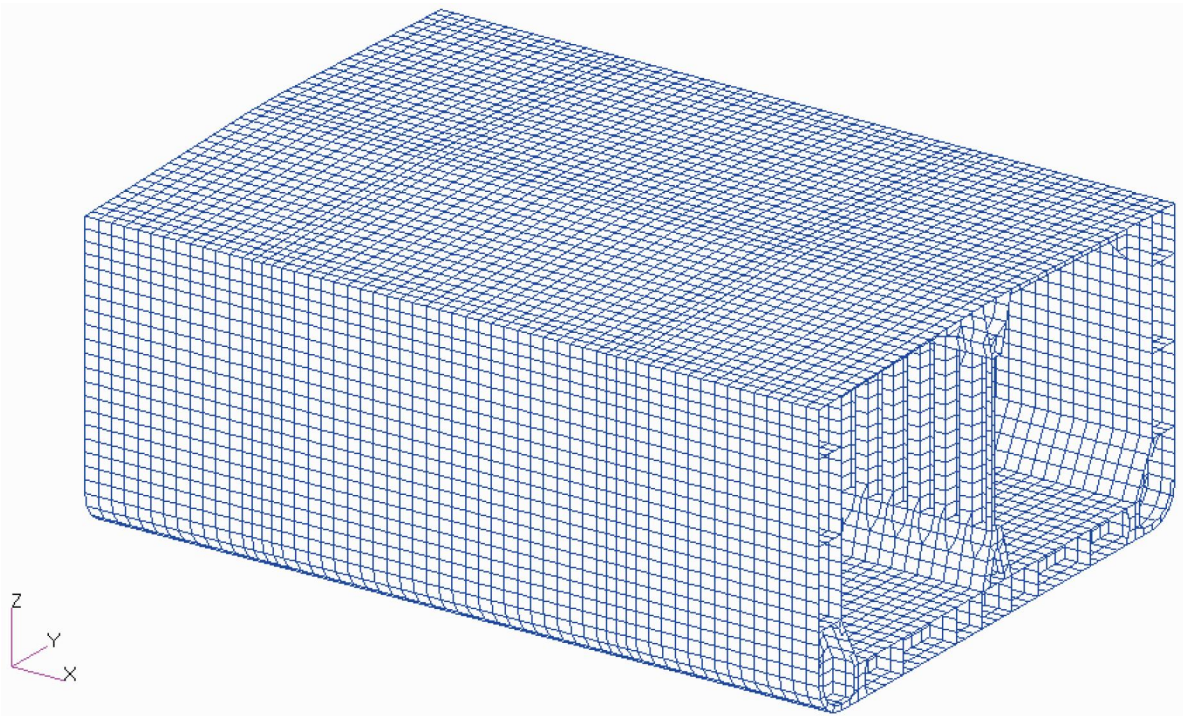



**Figure 4.1.1 Finite Element Model**

## 4.2 Boundary conditions

4.2.1 Boundary condition with the structures symmetrical to longitudinal centerline section

4.2.1.1 If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotations around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta_y = \theta_x = \theta_z = 0$.

4.2.1.2 If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo tanks and bottom plating are restrained, i.e.: $\delta_y = 0$.

4.2.2 Boundary conditions for local loads (see Table 4.2.2)

4.2.2.1 Symmetrical conditions are applied respectively to end planes A and B, the displacements in the longitudinal direction of nodes and the rotations around the two coordinate axes within the end plane are to be restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.2.2 Vertical spring elements are to be provided at intersections of side shell plating, inner hull plating and longitudinal bulkhead with forward and aft bulkheads in midship cargo tanks. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: $G$ — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ N/mm$^2$ for steel;

$A$ — shearing area of side shell plating, inner hull plating or longitudinal bulkhead plate in way of forward and aft bulkheads, in mm$^2$;

$l_H$ — length of midship cargo tank, in mm;

$n$ — number of nodes on vertical intersections of side shell plating, inner hull plating or longitudinal bulkhead plate.

**Boundary Conditions for Local Loads** **Table 4.2.2**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Longitudinal centerline section (half-breadth model) | – | Constraint | – | Constraint | – | Constraint |
| Node *G* (full-breadth model) | – | Constraint | – | – | – | – |
| End planes *A*, *B* | Constraint | – | – | – | Constraint | Constraint |

| | | | | | | |
|---|---|---|---|---|---|---|
| Intersection line *C* | – | – | Spring | – | – | – |

4.2.3 Boundary conditions for global load (see Table 4.2.3)

4.2.3.1 An independent point *H* is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the longitudinal bending moment is to be applied on the point *H*, and the degrees of freedom $\delta_x$, $\delta_y$ and $\delta_z$ of each member node for end planes is linked to the independent point.

4.2.3.2 The displacements of the independent point *H* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$; the displacement of the independent point *H* within the end plane *A* in longitudinal direction is restrained, i.e.: $\delta_x = 0$.

**Boundary Conditions for Global Load** **Table 4.2.3**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Longitudinal centerline section (half-breadth model) | – | Constraint | – | Constraint | – | Constraint |
| Node *G* (full-breadth model) | – | Constraint | – | – | – | – |
| End planes *A*, *B* | Link | Link | Link | – | – | – |
| Independent point *H* (end plate *A*) | Constraint | Constraint | Constraint | Constraint | Bending moment | – |
| Independent point *H* (end plate *B*) | – | Constraint | Constraint | Constraint | Bending moment | – |

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

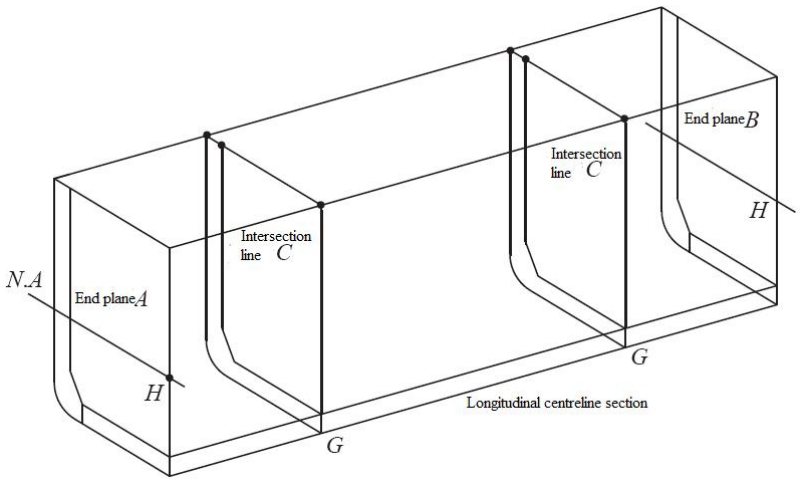



**Figure 4.2.4 Boundary Conditions**

## 5 YIELD STRENGTH EVALUATION

### 5.1 Allowable stresses

5.1.1 Strength evaluation is to be carried out for all primary members in the cargo tanks amidships (including bulkheads) within the longitudinal extent. The evaluation is to be based on the combined stress, which are derived from local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

5.1.2 The allowable stresses for primary structural members are given in Table 5.1.2.

**Allowable Stresses** **Table 5.1.2**

| Structural member | Allowable stress（N/mm²） | |
|---|---|---|
| | $[\sigma_e]$ | $[\tau]$ |
| Deck | 220/ *K* | – |
| Bottom shell plating, inner bottom plating | 220/ *K* | – |

| Structural member | Allowable stress（N/mm²） | |
|---|---|---|
| | $[\sigma_e]$ | $[\tau]$ |
| Side shell plating, inner hull plating, longitudinal bulkhead, horizontal girder in double hulls | 220/ $K$ | 115/ $K$ |
| Bottom girder | 235/ $K$ | 115/ $K$ |
| Double bottom floor | 175/ $K$ | 95/ $K$ |
| Transverse bulkhead | 175/ $K$ | 95/ $K$ |
| Side plating of lower, upper stools | 195/ $K$ | 95/ $K$ |
| Transverse web frame | 195/ $K$ | 95/ $K$ |
| Others | 195/ $K$ | – |

Note: $K$— material factor.

## 6 BUCKLING STRENGTH EVALUATION

### 6.1 Buckling safety factors

6.1.1 The standard thickness deduction of members is given in Table 6.1.1.

**Standard Thickness Deduction** **Table 6.1.1**

| Position | | Standard thickness deduction (mm) |
|---|---|---|
| Within 1.5 m below weather deck | Deck and shell plating | 1.0 |
| | Inner hull and longitudinal bulkhead | 2.0 |
| | Internal structure including transverse bulkhead① | 2.0 |
| Elsewhere | Shell plating | 1.0 |
| | Inner hull and longitudinal bulkhead | 1.0 |
| | Internal structure including transverse bulkhead① | 1.0 |

Note:
① In uncoated tanks for refined oils where an inert gas system is not fitted, the thickness deduction is to be increased by 1 mm.

6.1.2 The safety factor $\lambda$ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

**Minimum Buckling Safety Factor** **Table 6.1.2**

| Structural member | Minimum buckling safety factor |
|---|---|
| Deck | 0.8 |
| Bottom plating, inner bottom plating | 0.8 |
| Side shell plating, inner hull plating, sloping plating of hopper tank, longitudinal bulkhead | 0.8 |
| Double bottom girder, horizontal girder in double hulls | 1.0 |
| Transverse bulkhead, lower stool, upper stool | 0.8 |
| Web plating of transverse structure including midship web frame and bulkhead horizontal and vertical webs | 1.0 |

# CHAPTER 6 SINGLE HULL OIL TANKERS

## Section 1 GENERAL PROVISIONS

### 6.1.1 Application

6.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of oil tankers with single hull and single bottom or with single hull and double bottom.

6.1.1.2 Those not covered in this Chapter are to comply with the relevant provisions in Chapter 2 and Chapter 5 of this PART.

### 6.1.2 Structural arrangement

6.1.2.1 Subdivision, scantlings of cargo tank and height of double bottom, etc. are to be in compliance with Section 8, Chapter 1 of this PART.

6.1.2.2 For oil tankers of 65 m or over in length, deck, bottom and inner bottom in the cargo tank region are to be longitudinally framed, while the sides may either be longitudinally framed or transversely framed. For oil tankers of less than 65 m in length, all such framing may be transverse.

### 6.1.3 Minimum thickness

6.1.3.1 The minimum thicknesses of structural members in cargo tank regions, pump rooms, cofferdams and other void spaces are to comply with the requirements of 5.1.5 of Section 1, Chapter 5 of this PART.

## Section 2 SHELL PLATING AND DECKS

### 6.2.1 General requirements

6.2.1.1 The thickness of transversely framed shell plating and decks in the cargo tank region may be determined by the relevant provisions of this Section.

### 6.2.2 Bottom shell plating and bilge strake

6.2.2.1 The thickness $t$ of bottom shell plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.072sE^{-1}(L+170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$ — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

$d$ — draft, in m;

$L$ — length of ship, in m;

$F_b$ — reduction factor, see 2.2.5.6, Chapter 2 of this PART;

$K$ — material factor;

$E = 1+\frac{s^2}{S^2}$, $S$ being spacing of bottom girders or keels, in m;

$h_1$ — $0.26C$, to be taken as not greater than $0.2d$;

$C$ — coefficient, see 2.2.3.1, Chapter 2 of this PART.

6.2.2.2 The thickness of bilge strakes is not to be less than that of bottom shell plating obtained from the calculation in 6.2.2.1 and not to be less than the actual thickness of the adjacent bottom shell plating.

### 6.2.3 Plate keels

6.2.3.1 The breadth of plate keels is not to be less than the requirements in 5.2.3.1, Chapter 5 of this PART, while the thickness of plate keels is not to be less than that of bottom shell plating as required in this Section plus 2 mm and not less than that of the adjacent bottom shell plating.

### 6.2.4 Side shell plating

6.2.4.1 The thickness $t$ of side shell plating within $0.4L$ amidships is to comply with the following requirements:

(1) The thickness $t$ of side shell plating above 3$D$/4 from the base line is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness $t$ of side shell plating below $D$/4 from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: $s$, $d$, $L$, $h_1$, $K$ — see 6.2.2.1 of this Section;
$F_b$, $F_d$ — reduction factors, see 2.2.5.6, Chapter 2 of this PART;
$h_2$ — 0.5$C$, but not to be greater than 0.36$d$; $C$ being coefficient to be taken from 2.2.3.1, Chapter 2 of this PART;
$E$ = $1+\frac{s^2}{S^2}$, $S$ being spacing of side stringers, in m.

(3) The thickness of side shell plating above $D$/4 and below 3$D$/4 from the baseline is to be determined by interpolation from the values obtained from (1) and (2) above.
(4) For calculation of $t_1$, except for the minimum scope of higher tensile steels specified in Section 2 of Chapter 2, the material factor $K$ may be taken as 1.

### 6.2.5 Shear strakes

6.2.5.1 The breadth of the shear strakes is not to be less than 0.1$D$. The thickness of the shear strake plating is not to be less than that of the adjacent side shell plating.
6.2.5.2 The thickness $t$ of shear strakes within 0.4$L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: $s$, $d$, $L$, $F_d$, $E$, $S$, $K$ — see 6.2.4.1 of this Section.

### 6.2.6 Strength deck plating

6.2.6.1 The thickness $t$ of strength deck plating within 0.4$L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{DK} \quad \text{mm}$$

where: $s$ — spacing of transverses, in m, to be taken as not less than the standard spacing of frames;
$D$ — moulded depth, in m;
$E$ = $1+\frac{s^2}{S^2}$, $S$ being spacing of deck girders, in m;
$L$, $F_d$,$K$— see 6.2.5.2.

6.2.6.2 The thickness of strength deck plating is generally not to be less than that of side shear strakes obtained from the calculation in 6.2.5.2.

## Section 3 LONGITUDINAL BOTTOM FRAMING

### 6.3.1 General requirements

6.3.1.1 This Section applies to longitudinally framed single bottom structure.

### 6.3.2 Bottom longitudinals

6.3.2.1 The section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 10sDl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$D$ — moulded depth, in m;
$l$ — span of longitudinal, in m;
$K$ — material factor.

6.3.2.2 The connections of bottom longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. Where higher tensile steels are adopted, longitudinals are to be continuous through the transverse bulkheads.

6.3.2.3 Where the bottom longitudinals are cut in way of the bulkheads, the longitudinals are to be bracketed to the bulkheads. The scantlings of the bracket are to comply with the requirements of 1.2.6 of this PART, and the flange width of the bracket is not to be less than 8 times the thickness of the bracket. Bottom longitudinals are to be welded to the web and vertical stiffeners of bottom transverses.

### 6.3.3 Bottom transverses

6.3.3.1 The spacing of bottom transverses is not to be greater than 3.6 m.

6.3.3.2 Where one longitudinal bulkhead is fitted in the cargo tank region at the centerline of the ship, the section modulus $W$ and the section moment of inertia $I$ of the bottom transverses are not to be less than those obtained from the following formulae:

$$W = 11SDl^2K \quad \text{cm}^3$$
$$I = 10.5Wl/K \quad \text{cm}^4$$

where: $S$ — spacing of bottom transverses, in m;
$D$ — moulded depth, in m;
$l$ — span of bottom transverse, in m;
$K$ — material factor.

6.3.3.3 Where the continuous centerline girder complying with 6.3.4.2 of this Section are fitted in way of centre tanks of ships having two longitudinal bulkheads within the cargo tank region, the section modulus $W$ of the bottom transverses of the centre tanks and the net sectional area $A$ of the associated webs at span points of the longitudinal bulkheads are not to be less than those obtained by the following formulae:

$$W = C_1SDl^2K \quad \text{cm}^3$$
$$A = C_2SDlK \quad \text{cm}^2$$

where: $S$ — spacing of bottom transverses, in m;
$D$ — moulded depth, in m;
$l$ — span of bottom transverse, in m;
$K$ — material factor.

The bending moment factor $C_1$ and shear factor $C_2$ for centerline girders and bottom transverses are based on the number of bottom transverses in the tank and factor $C$, as given in Table 6.3.3.3 below (intermediate values are to be obtained by interpolation). The factor $C$ is to be calculated as follows:

$$C = \frac{l_G^3 I_F}{l_F^3 I_G}$$

where: $l_G$ — span of centerline girder, in m;
$l_F$ — span of bottom transverse, in m;
$I_G$ — section moment of inertia of centerline girder, in cm$^4$;
$I_F$ — section moment of inertia of bottom transverse, in cm$^4$.

**Table 6.3.3.3**

| $C$ | | | 0.02 | 0.06 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 bottom transverses | Girder | $C_1$ | 8.99 | 8.99 | 8.53 | 7.60 | 6.91 | 6.20 | 5.74 | 5.27 | 4.96 | 4.65 | 4.43 | 4.19 |
| | | $C_2$ | 0.84 | 0.84 | 0.81 | 0.73 | 0.68 | 0.62 | 0.59 | 0.54 | 0.51 | 0.48 | 0.46 | 0.45 |
| | Bottom transverse | $C_1$ | 1.55 | 1.74 | 1.98 | 2.48 | 2.85 | 3.22 | 3.47 | 3.66 | 3.84 | 4.03 | 4.15 | 4.28 |
| | | $C_2$ | 0.31 | 0.33 | 0.35 | 0.39 | 0.42 | 0.45 | 0.47 | 0.49 | 0.50 | 0.51 | 0.52 | 0.53 |
| 5 bottom transverses | Girder | $C_1$ | 12.71 | 12.25 | 11.63 | 10.23 | 9.24 | 8.22 | 7.53 | 6.82 | 6.29 | 5.74 | 5.43 | 5.12 |
| | | $C_2$ | 1.43 | 1.39 | 1.33 | 1.21 | 1.12 | 1.03 | 0.97 | 0.91 | 0.87 | 0.83 | 0.80 | 0.77 |
| | Bottom transverse | $C_1$ | 1.55 | 1.86 | 2.23 | 2.79 | 3.16 | 3.53 | 3.78 | 4.03 | 4.22 | 4.40 | 4.53 | 4.59 |
| | | $C_2$ | 0.32 | 0.34 | 0.37 | 0.41 | 0.44 | 0.47 | 0.49 | 0.51 | 0.53 | 0.54 | 0.55 | 0.56 |

Notes: (1) In the case of 2 bottom transverses, calculation may be performed as that for 3 bottom transverses, with $C_1$ being reduced by 20% and $C_2$ by 25% for centerline girders.
(2) In the case of 4 bottom transverses, the factor may be obtained by interpolation.

The net sectional area $A$ of the web at mid-span of the bottom transverse is not to be less than $\left(\frac{1}{1.6C_2} - 1\right)A$.

The above $W$ and $A$ may also be determined by direct calculation.

6.3.3.4 For ships having two longitudinal bulkheads within the cargo tank region, the scantlings (including the section modulus and the net sectional area of webs at span points) of bottom transverses of wing tanks are generally to be the same as those of bottom transverses of centre tanks.

6.3.3.5 The web depth of the bottom transverses is not to be less than 2.5 times the depth of the slot for the bottom longitudinals.

6.3.3.6 The ends of bottom transverse are to be bracketed to longitudinal bulkheads or ship side. The brackets are to comply with the requirements of 1.2.7 of this PART. Where connected to ship side, the brackets are as far as possible to form a ring system.

Where the side shell and longitudinal bulkheads are framed transversely in wing cargo tanks, the raised ends of bottom transverse in the tank are to extend to the lowest side stringer and to the lowest horizontal girder of the longitudinal bulkhead. Where the side shell and longitudinal bulkheads are framed longitudinally in wing cargo tanks, the bottom transverses in the tank together with web frames, longitudinal bulkhead vertical webs and deck transverses are to form a transverse framing structure. The radius of rounded corners of the connection of the transverse framing structure to bottom transverses in the tank is generally not to be less than the web depth of adjacent members. The face plate at the connection is to be continuous and have a sectional area not less than that of the face plate of bottom transverses.

6.3.3.7 The web thickness of bottom transverses is not to be less than $s/80$ ($s$ being the spacing of stiffeners). Vertical stiffeners are generally to be fitted on one side of the web plate of bottom transverses in line with the longitudinals. Where the web depth of bottom transverses exceeds $165t\sqrt{K}$ ($t$ being the web thickness, $K$ being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate.

The scantlings of vertical and horizontal stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

6.3.3.8 Bottom transverses are generally to be fitted with tripping brackets close to the toes of end brackets and elsewhere according to the relevant requirements in 1.2.5.4 of this PART.

### 6.3.4 Bottom centerline girder and bottom side girders

6.3.4.1 Where the length of the ship exceeds 70 m and one centerline longitudinal bulkhead is fitted, one intercostal bottom side girder is generally to be fitted at about $1/4B$ from the centerline on each side.

6.3.4.2 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be fitted. The section modulus of the continuous centerline girder and the net sectional area $A$ of the web at any section are not to be less than those obtained from the following formulae:

$$W = 10SDblK \quad \text{cm}^3$$

$$A = 1.45bDSK \quad \text{cm}^2$$

where: $b$ — supporting breadth, in m, taken as half the distance between span points of the bottom transverse at both sides;

$S$ — spacing of bottom transverses, in m;

$D$ — moulded depth, in m;

$l$ — span of the centerline girder, in m;

$K$ — material factor.

6.3.4.3 The web depth of the bottom centerline girder is not to be greater than that of the bottom transverses. The web thickness of the bottom centerline girder is not to be less than that of the bottom transverses plus 2 mm.

6.3.4.4 The web thickness and face plate scantlings of the intercostal bottom side girders are to be the same as those of the bottom transverses in way, while the depth may be half of that of the bottom transverses.

### 6.3.5 Strengthening and end connections of bottom centreline girder

6.3.5.1 Docking brackets are to be fitted on both sides of the bottom centreline girder, midway between the bottom transverses or between the bottom transverse and the transverse bulkhead, and are to be connected to a suitable bottom longitudinal. These brackets are to have a face plate or a flange. The thickness of the brackets is to be the same as that of the web plate of the bottom centreline girder. The bracket on one side of the centreline girder is to be extended and welded to the face plate of the centreline girder but on the other side may be terminated at a suitable horizontal stiffener.

Tripping brackets are also to be fitted close to the toes of end brackets of the continuous bottom centreline girder.

6.3.5.2 Horizontal stiffeners are to be fitted on one side of the web of the continuous centreline girder. Additional vertical stiffeners are to be suitably fitted in way of vertical webs and end brackets.

The horizontal stiffeners are to be spaced not more than $50t\sqrt{K}$ apart ($t$ being the web thickness of the centreline girder, $K$ being material factor), and the scantlings of the horizontal stiffeners and vertical stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

# Section 4 TRANSVERSE BOTTOM FRAMING

### 6.4.1 General requirements

6.4.1.1 This Section applies to transversely framed single bottom structure.

### 6.4.2 Bottom transverses

6.4.2.1 The solid floor is to be fitted at each bottom transverse. The web depth $h$, thickness $t$ and face plate sectional area $A$ are not to be less than those obtained from the following formulae:

$h = 42(B + d) - 70$ mm

$t = (0.01h + 3)\sqrt{K}$ mm, but need not be greater than 14 mm

$A = (4.8d - 3)K$ cm²

where: $B$ — breadth of ship, in m;

$d$ — draft, in m;

$K$ — material factor.

6.4.2.2 The thickness of the face plate of bottom transverses is not to be less than the web thickness of bottom transverses, while the breadth of the face plate is not to be less than 10 times its thickness, but need not be greater than 15 times.

### 6.4.3 Bottom centerline girder and bottom side girders

6.4.3.1 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be provided. The web thickness $t$ and face plate sectional area $A$ of the centerline girder throughout the cargo tank region are not to be less than those obtained from the following formulae:

$t = \sqrt{LK} + 2$ mm, and not less than 6 mm

$A = 0.67LK$ cm², and not less than 12.5 cm²

where: $L$ — length of ship, in m;

$K$ — material factor.

6.4.3.2 The bottom centerline girder is generally to be going through the whole ship. Where terminated in way of a transverse bulkhead, the web plating of the bottom centerline girder is gradually to rise to the bulkhead within one frame space, with the raised depth being twice the original one. The face plate of the bottom centerline girder is to be extended to the bulkhead, and to have 15° scarfing as shown in Figure 6.4.3.2.

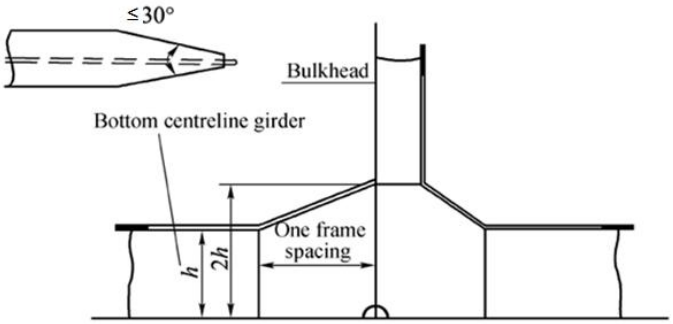



**Figure 6.4.3.2**

6.4.3.3 Where the breadth of the ship is equal to or less than 7 m, bottom side girders may not be provided; where the breadth is greater than 7 m but less than 12 m, at least one bottom side girder is to be provided at each side of the bottom centerline girder. Where the breadth of the ship is greater than 12 m, at least two bottom side girders are to be provided at each side of the bottom centerline girder. The bottom side girders are to be uniformly fitted so far as practicable and extended in the fore and aft direction.

6.4.3.4 The depth of bottom side girders is to be the same as that of the bottom transverses in way. The web thickness $t$ and the face plate area $A$ are not to be less than those obtained from the following formulae:

$t = \sqrt{LK}$ mm, and not less than 6 mm

$A = 0.25L + 5$ cm², and not less than10 cm²

where: $L$ — length of ship, in m;
$K$ — material factor.

# Section 5 LONGITUDINAL SIDE FRAMING

### 6.5.1 Side longitudinals

6.5.1.1 The section modulus $W$ of the side longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s\,(h + 1.2)\,l^2\,K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$h$ — vertical distance, in m, measured from the longitudinal under consideration to deck at side amidships, but not to be less than 2.5 m;
$l$ — span of longitudinal, in m;
$K$ — material factor.

6.5.1.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

6.5.1.3 Where longitudinal bottom and side framing is adopted, but bilge longitudinals are omitted, the spacing of transverses or equivalent bilge brackets are to comply with the requirements of 5.4.4.1, Chapter 5 of this PART.

6.5.1.4 Where the side longitudinals are cut at transverse bulkheads, these longitudinals are to be attached to the bulkheads by brackets. The arm length of the brackets are to be increased by 20% of that required in 1.2.6 of this PART, and the flange width of the brackets is not to be less than 8 times their thickness.

Side longitudinals are to be welded to the web plate of side transverses.

### 6.5.2 Side transverses

6.5.2.1 Side transverses are to be fitted in line with each solid floor in the longitudinally framed bottom.

6.5.2.2 The section modulus $W$ of side transverses is not to be less than that obtained from the following formula:

$$W = CS\,(h + 1.2)\,l^2\,K \quad \text{cm}^3$$

where: $S$ — spacing of side transverses, in m;
$h$ — vertical distance, in m, measured from the mid-span of the side transverse to deck at side;
$l$ — span of side transverse, in m;
$C$ — coefficient: $C = 11$, without horizontal cross ties; $C = 3.2$, with one horizontal cross tie; $C = 3$, with two horizontal cross ties;
$K$ — material factor.

6.5.2.3 The section moment of inertia $I$ of side transverses is not to be less than that obtained from the following formula:

$$I = 7.5Wl/K \quad \text{cm}^4$$

where: $W$ — section modulus of side transverses, in $\text{cm}^3$;
$l$ — span of side transverse, in m;
$K$ — material factor.

6.5.2.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side transverses, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4 of this PART.

6.5.2.5 The web thickness of side transverses is not to be less than $s/80$ ($s$ being the spacing of stiffeners or the depth of unstiffened web, in mm). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side transverses in line with every side longitudinal. Where the web depth of side transverses exceeds $165t\sqrt{K}$ ($t$ being the thickness of the web plate, $K$ being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5, Chapter 5 of this PART.

6.5.2.6 The connection of side transverses to deck transverses and bottom transverses is to form a transverse framing structure so far as practicable. The radius of rounded corners of the connection of the transverse framing structure is generally not to be less than the web depth of adjacent members. Where independent brackets are used at upper ends of side transverses, the scantlings of the brackets are to comply with the requirements of 1.2.7 of this PART.

The brackets connected to bottom transverses are to comply with the relevant requirements of 6.3.3.6 of this Chapter.

### 6.5.3 Cross ties

6.5.3.1 Where horizontal cross ties are to be arranged between side transverses and the vertical webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

## Section 6 TRANSVERSE SIDE FRAMING

### 6.6.1 Side frames

6.6.1.1 The section modulus $W$ of side frames is not to be less than that obtained from the following formula:

$$W = 11s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $s$ — spacing of side frames, in m;

$h$ — vertical distance, in m, measured from the mid-span of the side frame to deck at side, but not to be less than 2.5 m;

$l$ — span of side frame, in m, but not to be less than 2.5 m;

$K$ — material factor.

Where side transverses are fitted, the section modulus of side frames may be reduced by 15% from that obtained from the above formula.

It is recommended that the section modulus of side frames fitted in line with the bottom and deck transverses be suitably increased.

6.6.1.2 The depth and breadth of the brackets connecting the side frames to deck transverses are, in general, not to be less than the depth of the web of the deck transverses.

6.6.1.3 Side frames not in line with the bottom and deck transverses are to be attached to the deck and bottom plating by brackets. The arm length of these brackets is to be 20% more than that required in 1.2.6 of this PART. The brackets connected to deck are to have face plates or flanges not less than 80 mm, and are to extend to the nearest longitunudal of the deck and welded to it.

The bilge brackets are to be extended to the nearest bottom longitudinal and welded to it, covering the entire bilge. The breadth of face plates of bilge brackets is not to be less than 120 mm.

6.6.1.4 Where the lower end of side frames is lapped to the bilge brackets, the length of overlap is not to be less than twice the depth of the frames. Side frames are to be welded to the web plate of side stringers.

### 6.6.2 Side transverses

6.6.2.1 Where the moulded depth $D$ exceeds 11 m, or where the spacing of oiltight or non-oiltight transverse bulkheads exceeds 15 m, side transverses complying with the requirements of 6.5.2 of this Chapter are to be fitted in line with the solid floors in the longitudinally framed bottom. Where the bottom is transversely framed, the strengthening of side framing is to be specially considered. Where the side transverse does not support side stringers, the section modulus of the side transverse may be reduced by 20% from that required in 6.5.2.2 of this Chapter.

For the tripping brackets fitted to the web plate of side transverses, see 6.5.2.4 of this Chapter.

For the stiffeners fitted to the web plate of side transverse, see 6.5.2.5 of this Chapter.

For brackets connecting the side transverse to deck and bottom transverses, see 6.5.2.6 of this Chapter.

### 6.6.3 Side stringers

6.6.3.1 Where the moulded depth is less than or equal to 7.5 m, one side stringer is to be fitted; where the moulded depth is less than 6.0 m, however, side stringers may be omitted.

Where the moulded depth is more than 7.5 m, two side stringers are generally to be fitted.

6.6.3.2 The section modulus $W$ of side stringers is not to be less than that obtained from the following formula:

$$W = 12b\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: $b$ — width of supported plating, in m, to be taken as half the total length of the intersected side frame above and below the side stringer under consideration;

$h$ — vertical distance, in m, measured from side stringer to the tank top in way of longitudinal centreline;

$l$ — span of side stringer, in m, taken as the spacing of side transverses where side transverses are fitted;

$K$ — material factor.

Where two or more side stringers are fitted, the section modulus of the uppermost one is to be increased by 20% above that obtained from the above formula.

6.6.3.3 The web depth of side stringers is not to be less than 2.5 times the depth of the slot for the side transverses.
6.6.3.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side stringers, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4, Chapter 1 of this PART.
6.6.3.5 The web thickness of side stringers is not to be less than $s/80$ ($s$ being the spacing of stiffeners or the depth of unstiffened web, in m). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side stringers in line with every frame. Where the web depth of side stringers exceeds $165\,t\sqrt{K}$ ($t$ being the thickness of the web plate, $K$ being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.
6.6.3.6 The connection of ends of side stringers to transverse bulkheads are to comply with the following requirements: where side stringers are connected to transverse bulkhead plating, they are to gradually rise to the depth of twice the original one within the depth of about one web plate from bulkhead plating. The web plates of the stringers are to be welded to bulkhead plating. The face plates of the stringers are to extend to bulkheads. Where side stringers are connected to the horizontal girders of transverse bulkheads, they are to comply with the requirements of 1.2.7 of this PART.

### 6.6.4 Cross ties
6.6.4.1 Where horizontal cross ties are to be arranged between side stringers and horizontal webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

## Section 7 TRANSVERSE DECK FRAMING

### 6.7.1 Deck transverses
6.7.1.1 The section modulus $W$ and moment of inertia $I$ of deck transverses in the cargo tank region are not to be less than those obtained from the following formulae:

$$W = 10.8shl^2K \quad \text{cm}^3$$
$$I = 2.3Wl/K \quad \text{cm}^4$$

where: $s$ — spacing of transverses, in m;
$h$ — design deck head, in m, to be determined according to 2.8.1.1 of this PART, but not to be less than design pressure of the breathing valves of oil tanks;
$l$ — span of transverse, in m, but not less than 2.5 m;
$K$ — material factor.
6.7.1.2 Deck transverses are to be bracketed to side frames. The scantlings of the brackets are to comply with the requirements of 6.6.1.3 of this Chapter. Deck transverses are to penetrate continuous deck girders, and are to be welded to them.

### 6.7.2 Deck girders
6.7.2.1 On strength deck, continuous deck girders are generally to be fitted longitudinally in line with bottom girders.
6.7.2.2 The section modulus $W$ and moment of inertia $I$ of continuous deck girders are not to be less than those obtained from the following formulae:

$$W = 12bhl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $b$ — mean breadth, in m, of areas supported by deck girders;
$h$ — design deck head, in m, the same as that in 6.7.1.1 of this Section;
$l$ — span of deck girder, in m;
$K$ — material factor.
6.7.2.3 The web depth of deck girders is generally not to be less than 2.5 times the depth of deck transverse opening.
6.7.2.4 The connection of deck girders to transverse bulkheads or vertical webs of transverse bulkheads is to comply with the requirements of 1.2.7 of this PART.
6.7.2.5 Deck girders are to be fitted with tripping brackets as specified in 1.2.5.4 of this PART.

# Section 8 TRUNK STRUCTURE

### 6.8.1 General requirements

6.8.1.1 The trunk structure is as shown in Figure 6.8.1.2. As a part of strength deck, the trunk structure is to be efficiently scarfed into the main hull structure.

6.8.1.2 Where a trunk is fitted, design moulded depth $D_1$ is to be measured from the baseline to equivalent deck, the position of which is to be determined from the following formulae:

$$D_1 = D + 0.6\frac{b_t h_t}{B}, \qquad \text{for}\ \frac{b_t}{B} \le 0.8$$

$$D_1 = D + h_t\left(2.6\frac{b_t}{B} - 1.6\right), \quad \text{for}\ \frac{b_t}{B} > 0.8$$

where: $D$, $B$ — moulded depth and breadth of ship respectively, in m;

$b_t$, $h_t$ — mean breadth and height of trunk, in m, see Figure 6.8.1.2.

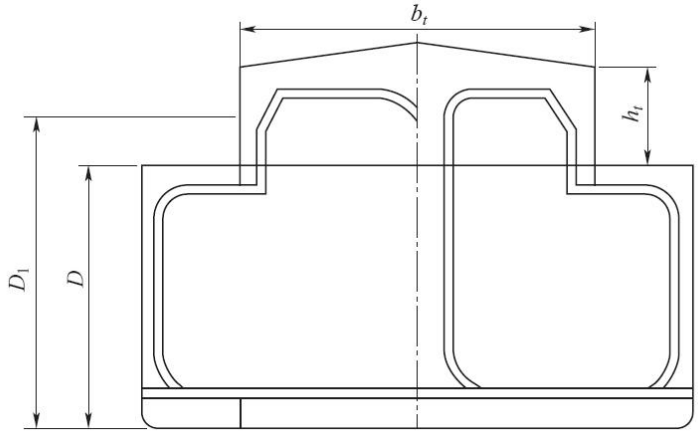



**Figure 6.8.1.2**

6.8.1.3 In calculation of side, deck, bottom and bulkhead scantlings where the moulded depth $D$ is involved, it is to be replaced by the design moulded depth $D_1$; where the design pressure head is measured to deck at side, it is to be increased by $D_1$-$D$.

### 6.8.2 Structural arrangement

6.8.2.1 The trunk structure is generally to extend over the full length of the cargo tanks and effectively in the fore and aft direction. The extension length of the trunk side plating at both ends is not to be less than 1.5 times the height of the trunk, and the ends are to form radiused extension brackets which are to have a face plate or flange.

6.8.2.2 The trunk deck and sides are generally to be longitudinally framed. Transverse strength members of the trunk deck are to be arranged in line with deck transverses.

6.8.2.3 The structural arrangement at the connection of the trunk side to deck transverses is to be such as to ensure adequate rigidity and continuity of strength.

6.8.2.4 Where deck is longitudinally framed and ship side is transversely framed, web frames are to be fitted in way of deck transverses. The considered span for the determination of the scantlings of deck transverses is to be measured from the span point at side to the longitudinal bulkhead. In addition, continuous deck girders are to be provided at trunk sides. The web depth of the continuous deck girders is not to be less than that of deck transverses. The sectional area of the face plate of continuous deck girders is not to be less than that of deck transverses.

6.8.2.5 Extension brackets and strengthened vertical stiffeners or equivalent structures are to be provided at fore and aft ends of the trunk so as to ensure the continuity of strength from the trunk structure into the main hull and superstructures. At fore and aft end bulkheads, the strength deck is to have radiused transition at corners of deck openings as required in 2.4.4 of this PART.

6.8.2.6 Where strength members or longitudinal stiffeners are fitted externally to the trunk, the arrangements and scantlings of the members are to be specially considered.

### 6.8.3 Scantlings of members

6.8.3.1 The thickness of the trunk top and side plating as well as that of the strength deck outside the trunk sides are to comply with the requirements of Section 3, Chapter 5 of this PART.
6.8.3.2 The scantlings of trunk longitudinals and web beams are not to be less than those of the strength deck framing as required in Section 6, Chapter 5 of this PART.
6.8.3.3 The hull section modulus, at the trunk and keel, for each transverse section within 0.4*L* amidships is to comply with the relevant requirements of Section 2, Chapter 2 of this PART. All continuous longitudinal members in the trunk may be considered for the hull section modulus amidships.

# CHAPTER 7 CONTAINER SHIPS

## Section 1 GENERAL PROVISIONS

### 7.1.1 Application

7.1.1.1 This Chapter applies to ships designed exclusively for the carriage of standard containers in holds and on deck.

7.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

7.1.1.3 Where the hull structural higher tensile steels of more than 50 mm and up to 100 mm in thickness with the minimum yield strength greater than 355 N/mm$^2$ are used on board container ships, the requirements of CCS Guidelines for Application of Thick Higher Strength Steel Plates for Ships are to be complied with.

7.1.1.4 Where the hull structural higher tensile steels with the yield strength 390 N/mm$^2$ are used for strength deck and coaming plating on board container ships, the material factor $K$ may be taken as 0.66 in accordance with 1.3.1 of Section 3, Chapter 1 of this PART, provided that:

(1) the plating thickness is to be more than 50 mm;

(2) the areas of higher tensile steels with 390 N/mm$^2$ is to be evaluated by means of fatigue spectrum analysis, the positions under evaluation are to include the connection between hatch coamings and supporting members, and other key positions with more severe response of bending moment and torque by hull girders, in addition to those as required in 4.1.5, Appendix 2 of this Chapter;

(3) the key positions of deck and hatch coaming are to be subject to construction monitoring in accordance with the requirements of CCS Guidelines for Construction Monitoring of Hull Structures.

### 7.1.2 Plans and documents

7.1.2.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following are to be submitted to CCS for approval:

(1) Stowage arrangement of containers;

(2) Details of reinforcement to structure in way of container corners/supports;

(3) Arrangement and structural connections of cell guides.

### 7.1.3 Arrangement and structural configuration

7.1.3.1 The basic structural configuration required by this Chapter includes a double bottom, and a double side skin construction with an efficient torsion box girder fitted at the topsides. Where the strength of the hull structure is ensured, a double bottom and a single side skin construction with the torsion box girder or an alternative equivalent structure may be adopted.

7.1.3.2 Longitudinal framing is to be adopted for the topside and also in the double bottom for ships over 100 m in length.

7.1.3.3 Under the hydrodynamic torque of the hull, the average torsional angle of hatch openings in the strength deck is generally not to exceed 0.006°/m and the elongation of the hatch opening diagonal is generally not to exceed 35 mm, except for open-top container ships.

### 7.1.4 Direct strength calculation and fatigue strength assessment for hull structure

7.1.4.1 For ships of 150 m or over in length or of the width of hatch openings in the strength deck greater than 0.85$B$ ($B$ being the breadth of ship), direct FE strength calculation for cargo holds is to be carried out according to the requirements of Appendix 2 of this Chapter.

For container ships of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of inner shell to inner bottoms.

7.1.4.2 For container ships complying with one of the following conditions, direct FE strength calculation and fatigue strength assessment for the whole ship are to be carried out according to the requirements of Appendix 2 of this Chapter:

(1) 250 m or over in length;

(2) where the breadth of ship is greater than 32.36 m;
(3) where the width of hatch openings in the strength deck greater than 0.85$B$ ($B$ being the breadth of ship);
(4) where the structural arrangement is of non-conventional type.

# Section 2 LONGITUDINAL STRENGTH

### 7.2.1 General requirements

7.2.1.1 Application

(1) Application

This Section applies to the following types of ships of 90 m and over in length: container ships and ships dedicated primarily to carry their loads in containers. For container ships up to or greater than 65 m but less than 90 m in length, the requirements of longitudinal strength are referred to in Section 2 of Chapter 2 of this PART.

(2) Load limitations

The wave loads as given in 7.2.2.3 of this Section apply to ships meeting the following criteria:

| | |
|---|---|
| Length | $90\ \text{m} \le L \le 500\ \text{m}$; |
| Proportion | $5 \le L/B \le 9$; $2 \le B/d \le 6$; |
| Block coefficient at scantling draught | $0.55 \le C_b \le 0.9$. |

For ships that do not meet all of the aforementioned criteria, special considerations such as direct calculations of wave induced loads may be required.

(3) Longitudinal extent of strength assessment

The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment are to be carried out in way of 0.2$L$ to 0.75$L$ with due consideration given to locations where there are significant changes in hull cross section, e.g. changing of framing system and the fore and aft end of the forward bridge block in case of two-island designs.

In addition, strength assessments are to be carried out outside this area. As a minimum assessments are to be carried out at forward end of the foremost cargo hold and the aft end of the aft most cargo hold.

(4) For container ships of 90 m and over in length and ships dedicated primarily to carry their loads in containers, the minimum section moduls $W_0$ at amidship of hull girder is to comply with the requirements of Section 2, Chapter 2 of this PART.

7.2.1.2 Symbols and definitions

(1) Symbols

$L$ length of ship, in m, see 1.1.2 of Chapter 1;

$B$ moulded breadth of ship, in m, see 1.1.2 of Chapter 1;

$C$ wave parameter, see 7.2.2.3(1);

$d$ draught, in m, see 1.1.2 of Chapter 1;

$C_b$ block coefficient, see 1.1.2 of Chapter 1;

$C_w$ waterplane coefficient at scantling draught $d$, to be taken as:

$$C_W = A_W / (LB);$$

$A_w$ waterplane area at scantling draught $d$, in m$^2$;

$R_{eH}$ minimum yield stress of material, in N/mm$^2$;

$K$ material factor;

$E$ Young's modulus, in N/mm$^2$. to be taken as $E = 2.06 \times 10^5$ N/mm$^2$ for steel;

$M_S$ vertical still water bending moment in seagoing condition, in kN·m, at the cross section under consideration;

$M_{Smax}$, $M_{Smin}$ permissible maximum and minimum vertical still water bending moments in seagoing condition, in kN·m, at the cross section under consideration, see 7.2.2.2(2);

$M_W$ vertical wave induced bending moment, in kN·m, at the cross section consideration;

$F_S$ vertical still water shear force in seagoing condition, in kN, at the cross section under consideration;

$F_{Smax}$, $F_{Smin}$ permissible maximum and minimum vertical still water shearing forces in seagoing condition, in kN, at the cross section under consideration, see 7.2.2.2(2);

$F_W$ vertical wave induced shearing force, in kN, at the cross section under consideration;

$q_v$ shear flow along the cross section under consideration, to be calculated according to Appendix 3 of this Chapter;

$f_{NL\text{-}Hog}$ non-linear correction factor for hogging, see 7.2.2.3(2);

$f_{NL\text{-}Sag}$ non-linear correction factor for sagging, see 7.2.2.3(2);

$f_R$ factor related to the operational profile, see 7.2.2.3(2);
$t_{net}$ net thickness, in mm, see 7.2.1.3(1);
$t_{res}$ reserve thickness, to be taken as 0.5 mm;
$I_{net}$ net vertical hull girder moment of inertia at the cross section under consideration, to be determined using net scantlings as defined in 7.2.1.3, in $m^4$;
$\sigma_{HG}$ hull girder bending stress, in $N/mm^2$, as defined in 7.2.2.5;
$\tau_{HG}$ hull girder shearing stress, in $N/mm^2$, as defined in 7.2.2.5;
$X$ longitudinal coordinate of a location under consideration, in m;
$z$ vertical coordinate of a location under consideration, in m;
$z_n$ distance from the baseline to the horizontal neutral axis, in m.

(2) Fore end and aft end

The fore end (FE) of the rule length of ship ($L$), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at the forward side of the stem.

The aft end (AE) of the rule length of ship ($L$), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at a distance $L$ aft of the fore end (FE).

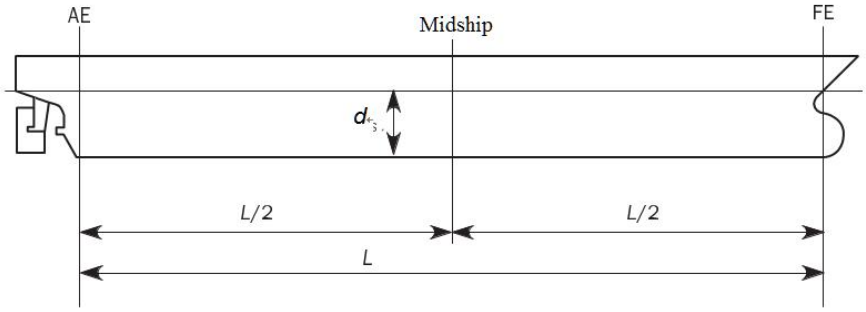



**Figure 7.2.1.2(1) Ends of lenth of ship ($L$)**

(3) Reference coordinate system

The ships geometry, loads and load effects are defined with respect to the following righthand coordinate system (see Figure 7.2.1.2(2)):

Origin: At the intersection of the longitudinal plane of symmetry of ship, the aft end of $L$ and the baseline.

$x$ axis: longitudinal axis, positive forwards.

$y$ axis: transverse axis, positive towards portside.

$z$ axis: vertical axis, positive upwards.

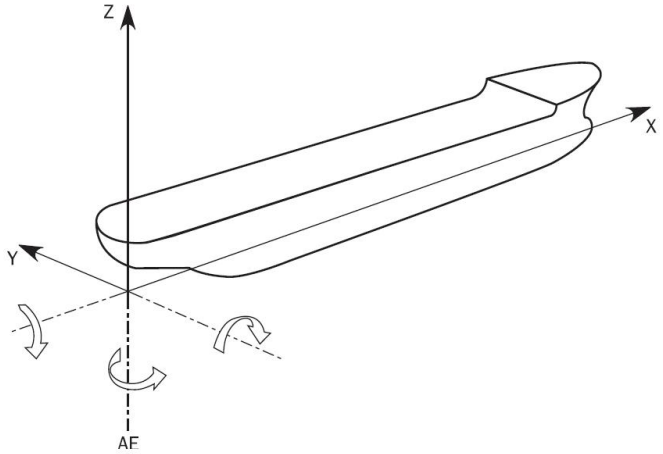



**Figure 7.2.1.2(2) Reference coordinate system**

7.2.1.3 Corrosion margin and net thickness

(1) Net scantling definition

The strength is to be assessed using the net thickness approach on all scantlings.

The net thickness, $t_{net}$, for the plates, webs and flanges is obtained by subtracting the voluntary addition $t_{vol_add}$ and the factored corrosion addition $t_c$ from the as built thickness $t_{as_built}$, as follows:

$$t_{net} = t_{as_built} - t_{vol_add} - \alpha t_c$$

where α is a corrosion addition factor whose values are defined in Table 7.2.1.3(1).

The voluntary addition, if being used, is to be clearly indicated on the drawings.

**Values of corrosion addition factor** **Table 7.2.1.3(1)**

| Structural requirement | Property/analysis type | $\alpha$ |
|---|---|---|
| Strength assessment (7.2.3) | Section property | 0.5 |
| Buckling strength (7.2.4) | Section property (stress determination) | 0.5 |
| | Buckling capability | 1.0 |
| Hull girder ultimate strength (7.2.5) | Section property | 0.5 |
| | Buckling/collapse capacity | 0.5 |

(2) Determination of corrosion addition

The corrosion addition for each of the two sides of a structural member, $t_{c1}$ or $t_{c2}$ is specified in Table 7.2.1.3(2). The total corrosion addition, $t_c$, in mm, for both sides of the structural member is obtained by the following formula:

$$t_c = (t_{c1} + t_{c2}) + t_{res}$$

For an internal member within a given compartment, the total corrosion addition, $t_c$ is obtained from the following formula:

$$t_c = 2t_{c1} + t_{res}$$

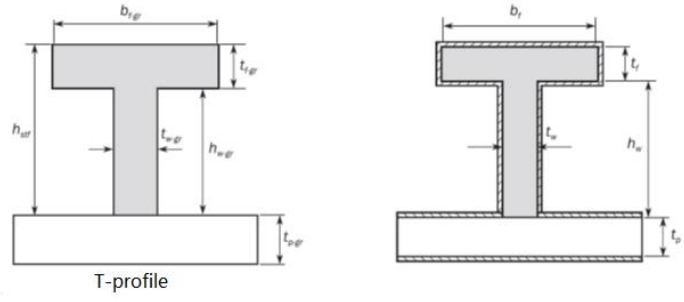
The corrosion addition of a stiffener is to be determined according to the location of its connection to the attached plating.

**Corrosion addition for one side of structural member** **Table 7.2.1.3(2)**

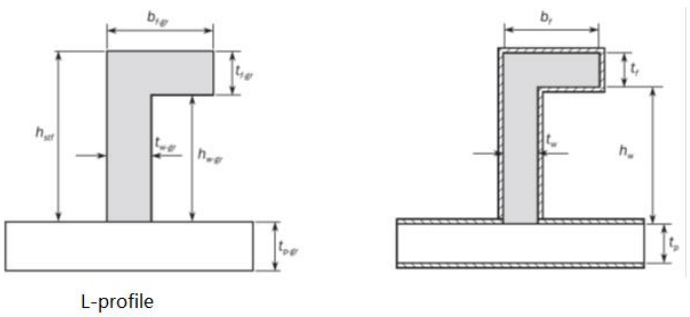
| Compartment type | One side corrosion addition $t_{c1}$ or $t_{c2}$ (mm) |
|---|---|
| Exposed to sea water | 1.0 |
| Exposed to atmosphere | 1.0 |
| Ballast water tank | 1.0 |
| Void and dry spaces | 0.5 |
| Fresh water, fuel oil and lube oil tank | 0.5 |
| Accommodation spaces | 0.0 |
| Container holds | 1.0 |
| Compartment types not mentioned above | 0.5 |

(3) Determination of net section properties

The net section modulus, moment of inertia and shear area properties of a supporting member are to be calculated using the net dimensions of the attached plate, web and flange, as defined in Figure 7.2.1.3. The net cross-sectional area, the moment of inertia about the axis parallel to the attached plate and the associated neutral axis position are to be determined through applying a corrosion magnitude of 0.5 $\alpha t_c$ deducted from the surface of the profile cross-section.



T-profile



L-profile

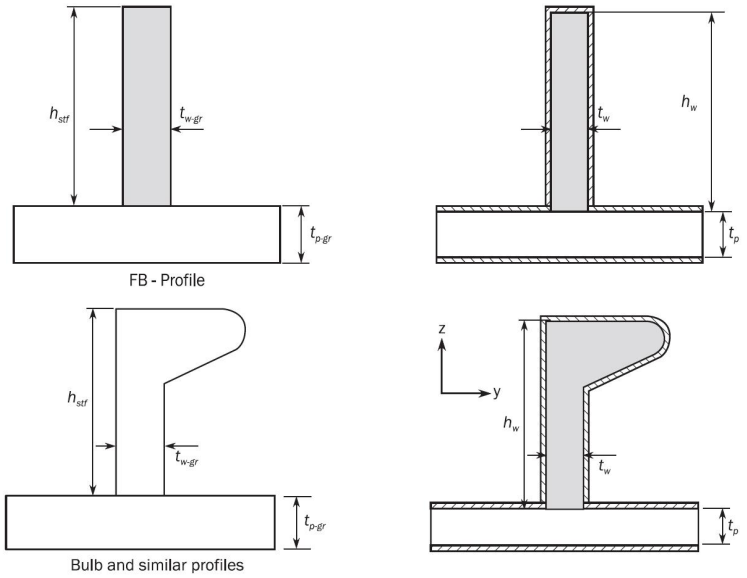



**Figure 7.2.1.3 Net sectional properties of supporting members**

### 7.2.2 Loads

7.2.2.1 Sign convention for hull girder loads

The sign conventions of vertical bending moments and vertical shear forces at any ship transverse section are as shown in Figure 7.2.2.1, namely:

- The vertical bending moments $M_S$ and $M_W$ are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces $F_S$, $F_W$ are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration. The shear forces in the directions opposite to above are negative.

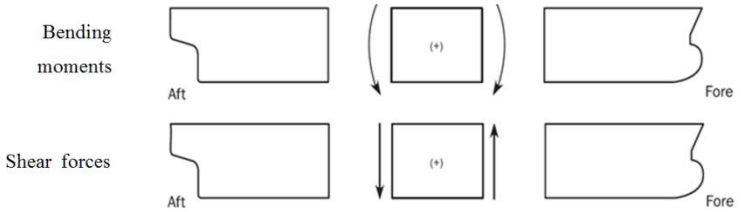



**Figure 7.2.2.1 Sign conventions of bending moments and shear forces**

7.2.2.2 Still water bending moments and shear forces

(1) General requirements

Still water bending moments, $M_S$ in kN·m, and still water shear forces, $F_S$ in kN, are to be calculated at each section along the ship length for design loading conditions as specified in 7.2.2.2(2).

(2) Design loading conditions

In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the $M_S$ and $F_S$ calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

The permissible vertical still water bending moments $M_{Smax}$ and $M_{Smin}$ and the permissible vertical still water shear forces $F_{Smax}$ and $F_{Smin}$ in seagoing conditions at any longitudinal position are to envelop:

- the maximum and minimum still water bending moments and shear forces for the seagoing loading conditions defined in the Loading Manual;
- the maximum and minimum still water bending moments and shear forces specified by the designer.

The Loading Manual is to include the relevant loading conditions, which envelop the still water hull girder loads for seagoing conditions, including those specified in 2.2.2.3 of Section 2, Chapter 2 of this PART.

7.2.2.3 Wave loads

(1) Wave parameter

The wave parameter is defined as follows:

$$C = 1 - 1.50\left(1 - \sqrt{\frac{L}{L_{ref}}}\right)^{2.2}, \text{ for } L \le L_{ref}$$

$$C = 1 - 0.45\left(\sqrt{\frac{L}{L_{ref}}} - 1\right)^{1.7}, \text{ for } L > L_{ref}$$

where: $L_{ref}$ — reference length of ship, in m, taken as:

$L_{ref} = 315C_W^{-1.3}$ for the determination of vertical wave bending moments according to 7.2.2.3(2);

$L_{ref} = 330C_W^{-1.3}$ for the determination of vertical wave shear forces according to 7.2.2.3(3).

(2) Vertical wave bending moments

The distribution of the vertical wave induced bending moments, $M_W$ in kN·m, along the ship length is given in Figure 7.2.2.3(2), where:

$$M_{W-Hog} = +1.5f_R L^3 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Hog}$$

$$M_{W-Sag} = -1.5f_R L^3 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Sag}$$

where: $f_R$ —factor related to the operational profile, to be taken as:

$f_R = 0.85$;

$f_{NL\text{-}Hog}$ — non-linear corrosion for hogging, to be taken as:

$$f_{NL-Hog} = 0.3\frac{C_B}{C_W}\sqrt{d}$$ , and not more than 1.1;

$f_{NL\text{-}Sag}$ — non-linear corrosion for sagging, to be taken as:

$$f_{NL-Sag} = 4.5\frac{1 + 0.2f_{Bow}}{C_W\sqrt{C_B}L^{0.3}}$$ , and not less than 1.0;

$f_{Bow}$ —bow flare shape coefficient, to be taken as:

$$f_{Bow} = \frac{A_{DK} - A_{WL}}{0.2Lz_f};$$

$A_{DK}$ — projected area in horizontal plane of uppermost deck, in $m^2$, including the forecastle deck, if any, extending from 0.8$L$ forward (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded;

$A_{WL}$ —waterplane area, in $m^2$, at draught $T$, extending from 0.8$L$ forward;

$z_f$ — vertical distance, in m, from the waterline at draught $d$ to the uppermost deck (or forecastle deck), measured at FE (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded.

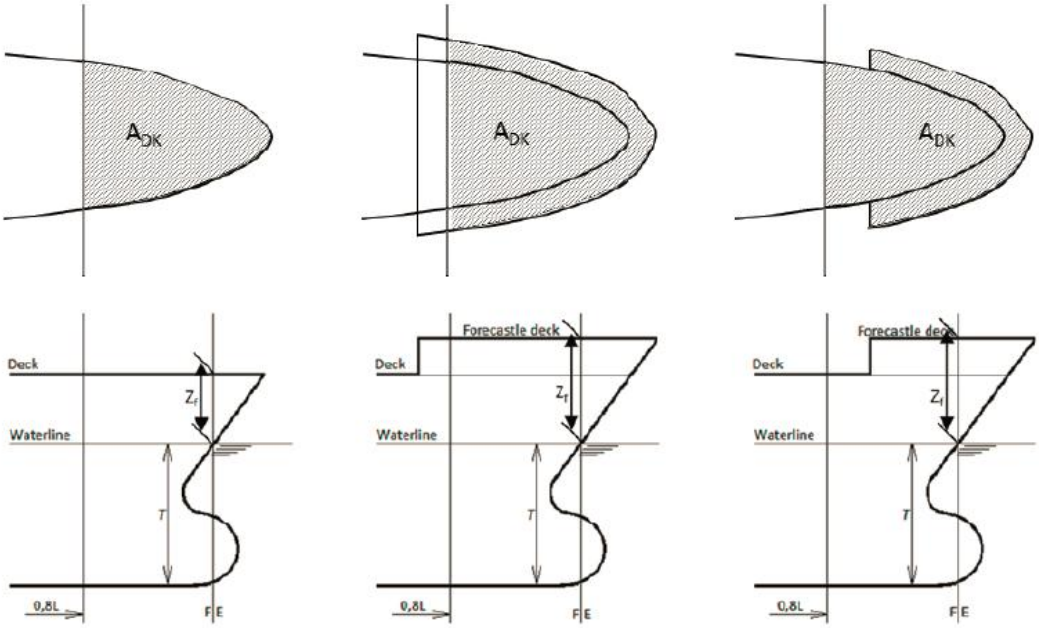



**Figure 7.2.2.3(1) Projected area $A_{DK}$ and vertical distance $z_f$**

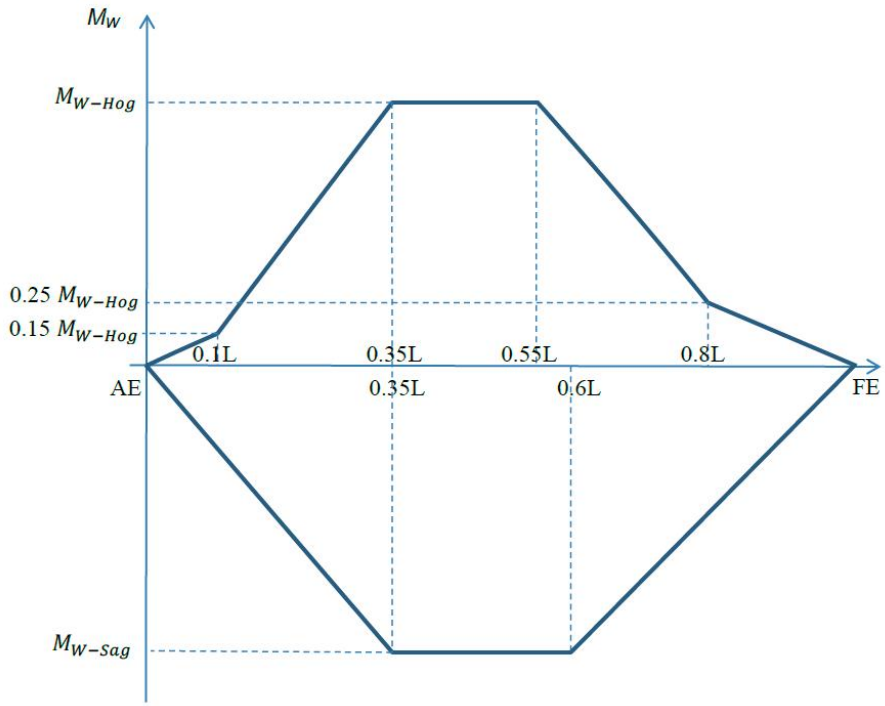



**Figure 7.2.2.3(2) Distribution of vertical wave bending moment $M_W$ along the ship length**

(3) Vertical wave shear force

The distribution of the vertical wave induced shear forces, $F_W$ in kN, along the ship length is given in Figure 7.2.2.3(3), where,

$$Fw_{Hog}^{Aft} = +5.2 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.3 + 0.7 f_{NL-Hog}\right)$$

$$Fw_{Hog}^{Fore} = -5.7 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Hog}$$

$$Fw_{Sag}^{Aft} = -5.2 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.3 + 0.7 f_{NL-Sag}\right)$$

$$Fw_{Sag}^{Fore} = +5.7 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.25 + 0.75 f_{NL-Sag}\right)$$

$$Fw^{Mid} = +4.0 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8}$$

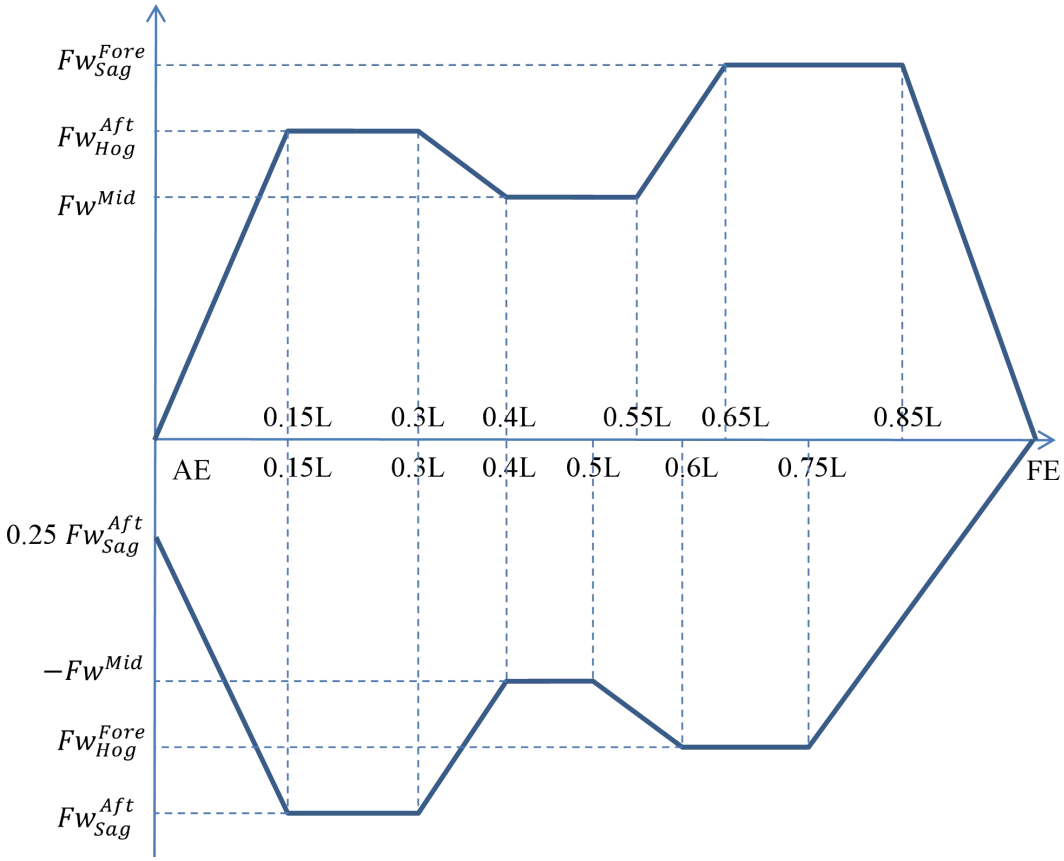



**Figure 7.2.2.3(3) Distribution of vertical wave shear force FW along the ship length**

7.2.2.4 Load cases

For the strength assessment, the maximum hogging and sagging load cases given in Table 7.2.2.4 are to be checked. For each load case the still water condition at each section as defined in 7.2.2.2 is to be combined with the wave condition as defined in 7.2.2.3, refer also to Figure 7.2.2.4.

**Combination of still water and wave bending moments and shear forces Table 7.2.2.4**

| Load case | Bending moment | | Shear force | |
|---|---|---|---|---|
| | $M_S$ | $M_W$ | $F_S$ | $F_W$ |
| Hogging | $M_{Smax}$ | $M_{WH}$ | $F_{Smax}$ for $x \leq 0.5L$ | $F_{Wmax}$ for $x \leq 0.5L$ |
| | | | $F_{Smin}$ for $x > 0.5L$ | $F_{Wmin}$ for $x > 0.5L$ |
| Sagging | $M_{Smin}$ | $M_{WS}$ | $F_{Smin}$ for $x \leq 0.5L$ | $F_{Wmin}$ for $x \leq 0.5L$ |
| | | | $F_{Smax}$ for $x > 0.5L$ | $F_{Wmax}$ for $x > 0.5L$ |

$M_{WH}$: Wave bending moment in hogging at the cross section under consideration, to be taken as the positive value of $M_W$ as defined in Figure 7.2.2.3(2).

$M_{WS}$: Wave bending moment in sagging at the cross section under consideration, to be taken as the negative value of $M_W$ as defined Figure 7.2.2.3(2).

$F_{Wmax}$: Maximum value of the wave shear force at the cross section under consideration, to be taken as the positive value of $F_W$ as defined Figure 7.2.2.3(3).

$F_{Wmin}$: Minimum value of the wave shear force at the cross section under consideration, to be taken as the negative value of $F_W$ as defined Figure 7.2.2.3(3).

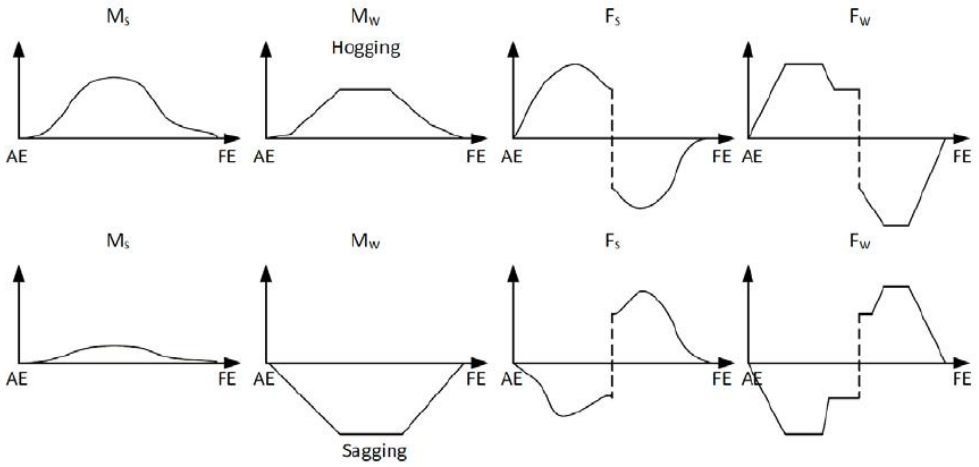



**Figure 7.2.2.4 Load combination to determine the maximum hogging and sagging load cases as given in Table 7.2.2.4**

7.2.2.5 Hull girder stress

The hull girder stresses, in N/mm$^2$, are to be determined at the load calculation point under consideration, for the "hogging" and "sagging" load cases defined in 7.2.2.4 as follows:

Bending stress:

$$\sigma_{HG} = \frac{\gamma_S M_S + \gamma_W M_W}{I_{net}}(z - z_n)10^{-3}$$

Shear stress:

$$\tau_{HG} = \frac{\gamma_S F_S + \gamma_W F_W}{t_{net} / q_v}10^3$$

where: $\gamma_S$, $\gamma_W$ — partial safety factor, to be taken as:

$\gamma_S = 1.0$

$\gamma_W = 1.0$

### 7.2.3 Strength assessment

7.2.3.1 General requirements

Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur adequate transitional structure is to be provided.

7.2.3.2 Stiffness criterion

The two load cases "hogging" and "sagging" as listed in 7.2.2.4 are to be checked.

The net moment of inertia, $I_{net}$, in m$^4$, is not to be less than:

$$I_{net} \geq 1.55L\left|M_S + M_W\right|10^{-7}$$

7.2.3.3 Yield strength assessment

(1) General acceptance criteria

The yield strength assessment is to check, for each of the load cases "hogging" and "sagging" as defined in 7.2.2.4, that the equivalent hull girder stress $\sigma_{eq}$, in N/mm$^2$, is less than the permissible stress $\sigma_{perm}$, in N/mm$^2$, as follows:

$$\sigma_{eq} < \sigma_{perm}$$

where: $\sigma_{eq} = \sqrt{\sigma_x^2 + 3\tau^2}$

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

$\gamma_1$ — partial safety factor for material, to be taken as $\gamma_1 = K\frac{R_{eH}}{235}$;

$\gamma_2$ — partial safety factor for load combinations and permissible stress, to be taken as:

- $\gamma_2 = 1.24$, for bending strength assessment according to 7.2.3.3(2);
- $\gamma_2 = 1.13$, for shear stress assessment according to 7.2.3.3(3).

(2) Bending strength assessment

The assessment of the bending stresses is to be carried out according to 7.2.3.3(1) at the following locations of the cross section:

- at bottom;
- at deck;
- at top of hatch coaming;
- at any point where there is a change of steel yield strength.

The following combination of hull girder stress as defined in 7.2.2.5 is to be considered:

$$\sigma_x = \sigma_{HG}$$

$$\tau = 0$$

(3) Shear strength assessment

The assessment of shear stress is to be carried out according to 7.2.3.3(1) for all structural elements that contribute to the shear strength capability①.

The following combination of hull girder stress as defined in 7.2.2.5 is to be considered:

$$\sigma_x = 0$$

$$\tau = \tau_{HG}$$

### 7.2.4 Buckling strength

7.2.4.1 Application

These requirements apply to plate panels and longitudinal stiffeners subject to hull girder positive bending and shear stresses. For the positive stress acted on plate panels and longitudinal stiffeners induced by hull girder bending, the buckling strength is to be taken into account only when the positive stress is the compression stress.

Definitions of symbols are given in Appendix 4 "Buckling Capacity".

7.2.4.2 Buckling criteria

The acceptance criterion for the buckling assessment is defined as follows:

$$\eta_{act} \le 1$$

where: $\eta_{act}$ — maximum utilisation factor as defined in 7.2.4.3.

7.2.4.3 Buckling utilisation factor

The utilisation factor, $\eta_{act}$ , is defined as the inverse of the stress multiplication factor at failure $\gamma_c$, see Figure 7.2.4.3.

$$\eta_{act} = \frac{1}{\gamma_c}$$

Failure limit states are defined in:

- Appendix 4 of this Chapter, 2 for elementary plate panels;
- Appendix 4 of this Chapter, 3 for overall stiffened panels;
- Appendix 4 of this Chapter, 4 for longitudinal stiffeners.

Each failure limit state is defined by an equation, and $\gamma_c$ is to be determined such that it satisfies the equation.

Figure 7.2.4.3 illustrates how the stress multiplication factor at failure $\gamma_c$ , of a structural member is determined for any combination of longitudinal and shear stress, where:

$\sigma_x$, $\tau$ — applied stress combination for buckling given in 7.2.4.4(1);

$\sigma_c$, $\tau_c$— critical buckling stresses to be obtained according to Appendix 4 of this Chapter for the stress combination for buckling $\sigma_x$ and $\tau$.

① Where the shear strength is checked beyond the range of 0.2$L$ to 0.75$L$, the permissible stress is generally to be in accordance with 7.2.3.3(1).

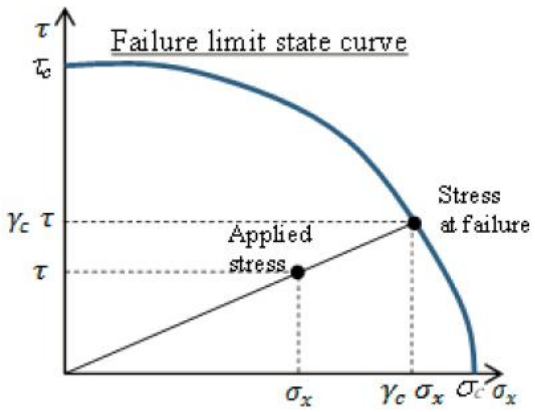



**Figure 7.2.4.3 Example of failure limit state curve and stress multiplication factor at failure**

7.2.4.4 Stress determination

(1) Stress combinations for buckling assessment

The following two stress combinations are to be considered for each of the load cases "hogging" and "sagging" as defined in 7.2.2.4. The stresses are to be derived at the load calculation points defined in 7.2.4.4(2).

(a) Longitudinal stiffening arrangement:

Stress combination 1 with:

$$\sigma_x = -\sigma_{HG}$$

$$\sigma_y = 0$$

$$\tau = 0.7\tau_{HG}$$

Stress combination 2 with:

$$\sigma_x = -0.7\sigma_{HG}$$

$$\sigma_y = 0$$

$$\tau = \tau_{HG}$$

(b) Transverse stiffening arrangement:

Stress combination 1 with:

$$\sigma_x = 0$$

$$\sigma_y = -\sigma_{HG}$$

$$\tau = 0.7\tau_{HG}$$

Stress combination 2 with:

$$\sigma_x = 0$$

$$\sigma_y = -0.7\sigma_{HG}$$

$$\tau = \tau_{HG}$$

(2) Load calculation points

The hull girder stresses for elementary plate panels (EPP) are to be calculated at the load calculation points defined in Table 7.2.4.4.

**Load calculation points (LCP) coordinates for plate buckling assessment**

**Table 7.2.4.4**

| LCP coordinates | Hull girder bending stress | | Hull girder shear stress |
|---|---|---|---|
| | Non horizontal plating | Horizontal plating | |
| *x* ordinate | Middle length of the EPP | | |
| *y* coordinate | Both upper and lower ends of EPP (points A1 and A2 in Figure 7.2.4.4) | Outboard and inboard ends of EPP (points A1 and A2 in Figure 7.2.4.4) | Middle point of EPP (point B in Figure 7.2.4.4) |
| *z* coordinate | Corresponding to *x* and *y* values | | |

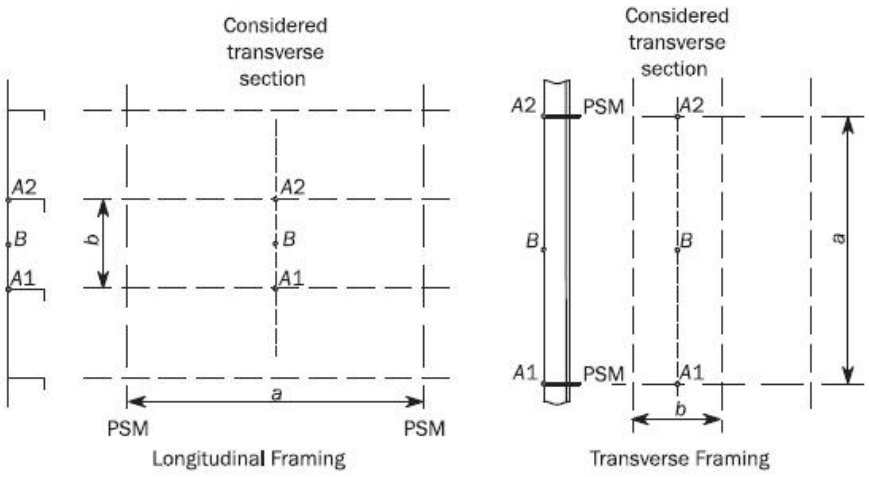



**Figure 7.2.4.4 LCP for plate buckling assessment (PSM stands for primary supporting members)**

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener;
- at the intersection point between the stiffener and its attached plate.

### 7.2.5 Hull girder ultimate strength

7.2.5.1 General requirements

The hull girder ultimate strength is to be assessed for ships with length $L$ equal to or greater than 150 m.

The acceptance criteria, given in 7.2.5.4 are applicable to intact ship structures.

The hull girder ultimate bending capacity is to be checked for the load cases "hogging" and "sagging" as defined in 7.2.2.4.

7.2.5.2 Hull girder ultimate bending moments

The vertical hull girder bending moment, $M$ in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_S M_S + \gamma_W M_W$$

where: $M_s$ — permissible still water bending moment, in kN·m, defined in 7.2.2.2;

$M_w$ — vertical wave bending moment, in kN·m, defined in 7.2.2.3;

$\gamma_S$ — partial safety factor for the still water bending moment, to be taken as: $\gamma_S$ = 1.0;

$\gamma_W$ — partial safety factor for the vertical wave bending moment, to be taken as:

$\gamma_W$ = 1.2.

7.2.5.3 Hull girder ultimate bending capacity

(1) General requirements

The hull girder ultimate bending moment capacity, $M_U$ is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses.

(2) Determination of hull girder ultimate bending moment capacity

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment $M$ versus the curvature $\chi$ of the transverse section considered ($M_{UH}$ for hogging condition and $M_{US}$ for sagging condition, see Figure 7.2.5.3). The curvature $\chi$ is positive for hogging condition and negative for sagging condition.

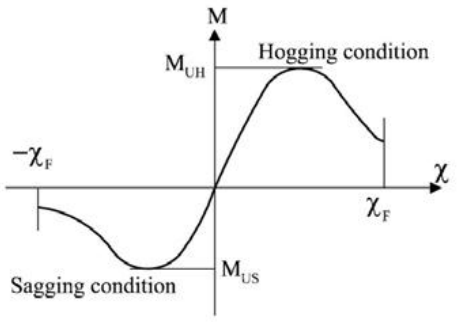



**Figure 7.2.5.3 Bending moment $M$ versus curvature $\chi$**

The hull girder ultimate bending moment capacity $M_U$ is to be calculated using the incremental-iterative method as given in Appendix 5 of this Chapter or using an alternative method as indicated in Appendix 5.

7.2.5.4 Acceptance criteria

The hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where: $M$ — vertical bending moment, in kN·m, to be obtained as specified in 7.2.5.2

$M_U$ — hull girder ultimate bending capacity, in kN·m, to be obtained as specified in 7.2.5.3;

$\gamma_M$ — partial safety factor for the hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties, to be taken as: $\gamma_M$ =1.05;

$\gamma_{DB}$ — partial safety factor for the hull girder ultimate bending moment capacity, covering the effect of double bottom bending, to be taken as:

- for hogging condition: $\gamma_{DB}$ = 1.15;
- for sagging condition: $\gamma_{DB}$ = 1.0.

For cross sections where the double bottom breadth of the inner bottom is less than that at amidships or where the double bottom structure differs from that at amidships (e.g. engine room sections), the factor $\gamma_{DB}$ for hogging condition may be reduced based upon agreement.

### 7.2.6 Additional requirements for large container ships

7.2.6.1 General requirements

The requirements of 7.2.6.2 and 7.2.6.3 are applicable, in addition to requirements of 7.2.3 to 7.2.5, to container ships with a breadth $B$ greater than 32.26 m.

7.2.6.2 Yielding and buckling assessment

Yielding and buckling assessments are to be carried out taking into consideration additional hull girder loads (wave torsion, wave horizontal bending and static cargo torque), as well as local loads. All in-plane stress components (i.e. bi-axial and shear stresses) induced by hull girder loads and local loads are to be considered. See 3 of appendix 2 to this Chapter for detailed analysis methods.

7.2.6.3 Whipping

Hull girder ultimate strength assessment is to take into consideration the whipping contribution to the vertical bending moment. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

## Section 3 DECK STRUCTURE

### 7.3.1 General requirements

7.3.1.1 In addition to the requirements of Sections 4 and 8, Chapter 2 of this PART, the scantlings of the deck structure are to comply with the requirements for the longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

7.3.1.2 The strength deck throughout the region of container holds is to be longitudinally framed and the scantlings of the structural members of the strength deck determined in accordance with the hull section modulus required in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter are to be kept unchanged over the region of container holds.

7.3.1.3 In order to ensure the hull structural strength, particular attention is to be paid to continuity of the deck structure and abrupt changes of shape, section or plate thickness are to be avoided. Effective transition arrangements are to be fitted at both end structures of the deck opening length. Arrangement in way of hatch corners and openings are to be such as to minimize the creation of stress concentrations.

7.3.1.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings exceeds 12 mm, a transition plate with a thickness equal to the mean of the adjacent plate thicknesses is to be fitted.

7.3.1.5 Where the lower deck acts as a primary support for the side framing, the deck plating thickness may be required to be suitably increased.

### 7.3.2 Cross deck strips

7.3.2.1 Where the cross deck strips of the strength deck form the top of a transverse bulkhead, their breadth $b$ is not to be less than that obtained from the following formula:

$$b = 1000 + 1.5L \quad \text{mm}$$

where: $L$ — length of ship, in m.

7.3.2.2 Where a transverse bulkhead top box is fitted, a reduced width of cross deck strips of the strength deck may be considered by calculation as appropriate.

7.3.2.3 In addition to complying with the requirement of 2.4.2.2 of this PART, the thickness $t$ of cross deck strips of the strength deck is not to be less than that obtained from the following formula:

$$t = 10 + 0.01L \quad \text{mm}$$

where: $L$ — length of ship, in m.

7.3.2.4 The thickness $t$ of cross deck strips of the second tier deck below the strength deck is not to be less than that obtained from the following formula, but not less than 8 mm:

$$t = 12s \quad \text{mm}$$

where: $s$ — spacing of beams, in m, to be taken as not less than the standard spacing of beams.

7.3.2.5 The thickness of cross deck strips of other decks below the second tier deck may be 8 mm.

7.3.2.6 The cross deck strips are to be sufficiently stiffened in the transverse direction, and the thickness of the strips is to be increased locally in way of stress concentration.

7.3.2.7 The ends of cross deck strips are to be effectively connected to the torsion box structures.

### 7.3.3 Strength deck girders

7.3.3.1 Girders supporting the longitudinal coaming plating are to be fitted under the strength deck (except where torsion box structures are fitted).

7.3.3.2 The strength deck girders are to be continuous throughout the container hold area, including the engine room where this is situated between container holds.

7.3.3.3 The ends of strength deck girders are to be integrated into the structures outside the container hold area. Special consideration is to be given to the connection of the girders with the transverse box girders.

### 7.3.4 Deck openings

7.3.4.1 The corners of hatchway openings in the strength deck are to be rounded. The radius of hatch corners near the ship's sides is not to be less than $0.35 + 0.0005L$ m ($L$ being the length of ship, in m), and the radius of hatch corners in way of the intersection of deck girders with cross deck strips is not to be less than 0.25 m. For rounded corners with negative radii, the designer is to provide technical reasons.

7.3.4.2 The radius of the hatch corners of the cargo hatchway openings adjacent to the engine room is to be made as large as practicable, with a radius of approximately $0.04B$ mm ($B$ being the breadth of ship, in m).

7.3.4.3 Insert plates are required at the hatch corners and to have a thickness increased by 15% above that of the strength deck plating. For container holds adjacent to the engine room, such insert plates are to be increased in thickness by 25% above that of the strength deck plating but not less by 4 mm and not more than 7 mm, and they are to be made of the same material as the strength deck. If the thickness of the insert plate can not meet above requirements, direct calculation method covering yield, buckling and fatigue is to be adopted for verification. The extension of the insert plates is to comply with Figure 7.3.4.3 ($R$ is the radius of hatch corner, $e$ is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing).

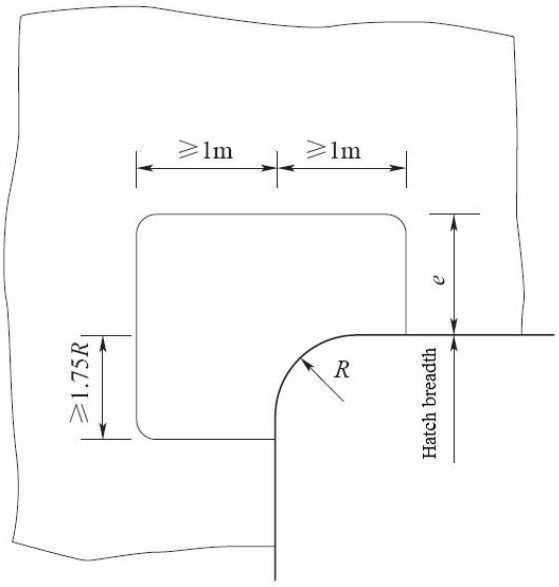



**Figure 7.3.4.3**

7.3.4.4 Openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

**7.3.5 Hatch coamings**

7.3.5.1 Where the hatch coaming is to be continuous over the entire opening area, the ends of the coaming are to have an appropriate structural transition.

7.3.5.2 The structure of hatch coamings is to comply with the relevant requirements in Section 20 of Chapter 2 of this PART.

## Section 4 SHELL PLATING

**7.4.1 Bottom plating and bilge strakes**

7.4.1.1 In addition to the requirements of Section 3 of Chapter 2 of this PART, the thickness of bottom plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

7.4.1.2 For transversely framed bottom plating and bilge strakes, special attention is to be paid to their buckling strength.

**7.4.2 Sheer strake and side shell plating**

7.4.2.1 In addition to the relevant requirements of Section 3 of Chapter 2 of this PART, the thickness of sheer strake and side shell plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter. At positions where high forces are present and at positions of the side shell plating where the double side skin structures terminate, local increases in thickness may be required.

7.4.2.2 The difference in thickness between the sheer strake and the shell plating below is not to exceed 1/2 of the thickness of sheer strake.

## Section 5 SIDE FRAMING

**7.5.1 Single side skin framing**

7.5.1.1 The arrangement and the scantlings of side framing are to comply with the requirements of Section 7, Chapter 2 of this PART. CCS may require that direct calculation be carried out for checking the strength of the primary supporting members.

7.5.1.2 Where longitudinal side framing is adopted, the web frames are to be arranged in line with the solid floors in the double bottom and the transverse frames in the torsion box to form a ring system so as to ensure the transverse strength of the ship.

### 7.5.2 Double side skin framing

7.5.2.1 The minimum plate thickness $t$ of transverse frames and horizontal flats (including perforated flats) within the double side skin construction is not to be less than that obtained from the following formula, but need not be greater than 9 mm:

$$t = 7.5 + 0.015L \quad \text{mm}$$

where: $L$ — length of ship, in m.

7.5.2.2 Transverse frames and horizontal flats are to be fitted with stiffening members and their thickness is to be increased locally where high shear forces are present.

## Section 6 DOUBLE BOTTOM

### 7.6.1 General requirements

7.6.1.1 Unless otherwise stated by this Section, the scantlings of structural members of double bottom are to comply with the relevant provisions of Section 6, Chapter 2 of this PART, but local stiffening is to be required under container corner seatings. Where the double bottom is interconnected with side tanks or deep cofferdams, the watertight floors and watertight girders are to comply with the requirements for deep tanks in Section 13 of Chapter 2 of this PART.

7.6.1.2 The requirements of 2.6.9.2(2), Section 6, Chapter 2 of this PART do not apply to the cargo holds carrying containers only.

7.6.1.3 For container ships of 150 m and over in length, the double bottom structure may comply with the requirements of 7.9.10 of this Chapter, except 7.9.10.12.

### 7.6.2 Girders and floors

7.6.2.1 Side girders are to be arranged under container corner seatings.

7.6.2.2 Vertical or horizontal stiffeners are to be fitted for girders in region of container holds, the height of stiffener is normally not less than 150 mm. When the length of ship is less than 150 m, the height of stiffener is not to be less than $L$ (mm) but not less than 50 mm.

7.6.2.3 For double bottoms longitudinally framed, solid floors are to be fitted under transverse bulkheads and below mid-hold or quarter-length-of-hold supporting structures.

7.6.2.4 The thickness of solid floors in region of container holds is to comply with the following requirements:

(1) The thickness $t$ of solid floor is not to be less than the value obtained from the following formula, but need not be greater than 12 mm:

$$t = 0.6\sqrt{LK} + 2.5 \quad \text{mm}$$

where: $L$ — length of ship;

$K$— material factor.

(2) In addition to complying with the requirements of (1) of this paragraph, the thickness $t$ of watertight floors is not to be less than that obtained from the following formula:

$$t = 0.02L\sqrt{K} + 7 \quad \text{mm}$$

where: $L$ and $K$ are defined in (1) of this paragraph.

7.6.2.5 For longitudinally framed containership, the thickness $t$ of the centre girders in region of container holds is not to be less than:

$$t = f_{db}\left(0.0077h_0 + 4\right)\sqrt{K} \quad \text{mm}$$

The thickness $t$ of side girder in region of container holds is not to be less than the value obtained from the following formula:

$$t = f_{db}\left(0.0077h_0 + 1\right)\sqrt{K} \quad \text{mm}$$

where: $f_{db}$ —correction factor of height of double bottom;

$f_{db} = 1$ when $L<150$m;

$f_{db} = h_0/h_a$ when $L \geq 150$m, but not to be less than 0.9; Where the longitudinal girder complies with the requirements for direct calculation of global strength of ship in Appendix 2, $f_{db} = h_0/h_a$ but not to be less than 0.85.

$h_0$ — considered height of double bottom, in mm, see Section 6 of Chapter 2;

$h_a$ — actual height of double bottom, in mm;

$K$ — material factor.

7.6.2.6 Where container holds are fitted between engine room and aft peak tank, the primary members at bottom are to comply with relevant requirements in Section 6, Chapter 2 of this PART.
7.6.2.7 For double bottom framed longitudinally and fitted with center girders, brackets leading to adjacent longitudinals are to be fitted respectively at both sides of the center girder between the solid floors.
7.6.2.8 Where torsion box center girder is used for double bottom framed longitudinally, the arrangement and the section modulus of web frame ring are to comply with relevant requirements of 7.9.10.6 of Section 9 of this Chapter.

### 7.6.3 Supporting structure of double bottom

7.6.3.1 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or other equivalent structures.

## Section 7 BULKHEADS

### 7.7.1 Inner skin longitudinal bulkheads

7.7.1.1 In addition to the relevant requirements of Sections 12 and 13 of Chapter 2 of this PART, the scantlings of inner skin longitudinal bulkheads are to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.
7.7.1.2 The longitudinal members of inner skin longitudinal bulkheads are to be continuous throughout the container hold area and maintained continuous in way of the machinery space where this is situated between container holds.
7.7.1.3 Where the inner skin bulkheads are stepped, the scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap having a length of not less than 3 frame spacings for transition.
7.7.1.4 Adequate transition arrangements are to be fitted at both ends of the inner skin longitudinal bulkhead.
7.7.1.5 The difference in thickness between the top strake and the bulkhead plating below (at the torsion box) is not to exceed 25 mm.

### 7.7.2 Watertight transverse bulkheads

7.7.2.1 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively. Where the depth to breadth ratio of the bulkhead is large, the scantlings of such vertical webs are to be determined by direct calculation.

## Section 8 BOW SIDE STRUCTURE STRENGTHENING

### 7.8.1 General requirements

7.8.1.1 The bow (including forecastle) side structure is to be strengthened within 0.1$L$ aft of the fore perpendicular above the summer load line. Where the maximum flare angle α at 0.15$L$ from forward perpendicular (see Figure 7.8.1.3(1)) is greater than 40 degrees, the strengthened longitudinal extent is to be extended to 0.15$L$ from forward perpendicular. The scantlings of side members in the strengthened area are to comply with the requirements of this Section.
7.8.1.2 In addition to the requirements of this Section, the bow side structure is to comply with the other relevant requirements in this PART.
7.8.1.3 The bow slamming head $h_s$ under consideration is to be obtained from the following formula:

$$h_s = C_s\left(0.22 + 0.15\tan\alpha\right)\left(0.4V\sin\beta + 0.6\sqrt{L}\right)^2 \quad \text{m}$$

where: $C_s$ = 0.144 ($C$ – 0.5$h_1$), and not to be greater than 0.8;

where: $h_1$ — vertical distance between summer load line and the point under consideration, in m, see Figure 7.8.1.3(1). For shell plating, the point is to be taken at centre of plate panel; for members, the point is to be taken at mid-span;

$C$ — coefficient of wave, see 2.2.3.1 of this PART;

$\alpha$ — flare angle at the point under consideration, defined as angle between vertical line and shell plating tangent in the cross section, in degree, see Figure 7.8.1.3(1);

$\beta$ — entrance angle at the point under consideration, defined as angle between centreline and shell plating tangent in the horizontal plane, in degree, see Figure 7.8.1.3(2);

$V$ — maximum service speed, in kn;

$L$ — length of ship, in m, but need not be taken as greater than 250 m.

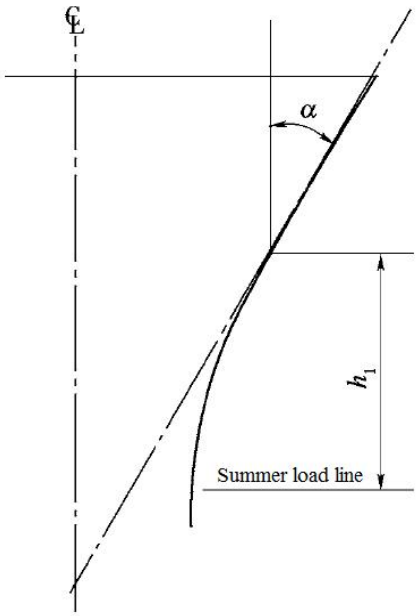



**Figure 7.8.1.3(1)**

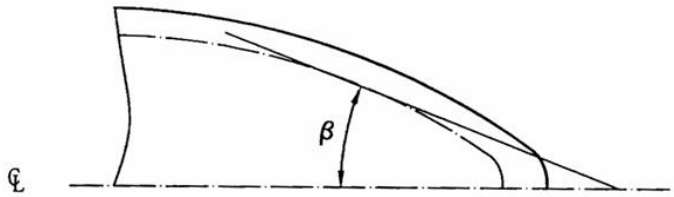



**Figure 7.8.1.3(2)**

### 7.8.2 Shell plating

7.8.2.1 The thickness $t$ of shell plating is not to be less than that obtained from the following formula:

$$t = 3.2\, b_{r1}\, s\sqrt{h_s K} + 1.5 \quad \text{mm}$$

where: $b_{r1}$ — coefficient, to be taken from the following, and not to be less than 0.72:

$b_{r1} = 1.0$ $\qquad \frac{s}{l} \le 0.4$

$b_{r1} = 1.187 - 0.467\frac{s}{l}$ $\qquad \frac{s}{l} > 0.4$

where: $s$ — spacing of secondary members, in m;

$l$ — span of secondary member, in m;

$h_s$ — bow slamming head under consideration, see 7.8.1.3 of this Section;

$K$ — material factor.

### 7.8.3 Secondary members

7.8.3.1 The section modulus $W$ and the web sectional area $A$ of secondary members such as side longitudinals or side frames are not to be less than those obtained from the following formulae:

$$W = 2.7 s h_s l^2 K \quad \text{cm}^3$$
$$A = 0.38 b_{r2} l s h_s K \quad \text{cm}^2$$

where: $b_{r2} = 1 - \frac{s}{2l}$;

$s$ — spacing of secondary members, in m;

$h_s$ — bow slamming head under consideration, see 7.8.1.3 of this Section;

$l$ — span of secondary member, in m;

$K$ — material factor.

7.8.3.2 Where the angle between web plating and shell plating of secondary members such as side longitudinals or side frames is less than 70º, tripping brackets are to be provided at mid-span of the members to improve the transverse stability of plate panels.

### 7.8.4 Primary members

7.8.4.1 The section modulus $W$ and the web sectional area $A$ of primary members such as side horizontal girders or vertical webs are not to be less than those obtained from the following formulae:

$$W = 2.1Sh_s l^2 K \quad \text{cm}^3$$

$$A = 0.265Sh_s l K \quad \text{cm}^2$$

where: $S$ — spacing of girders or webs, in m;

$h_s$ — bow slamming head under consideration, see 7.8.1.3 of this Section;

$l$ — span of girder or web, in m;

$K$ — material factor.

## Section 9 ADDITIONAL REQUIREMENTS FOR CONTAINER SHIPS OF GREATER THAN 250 M IN LENGTH

### 7.9.1 General requirements

7.9.1.1 This Section applies to large full container ships of more than 250 m in length.

7.9.1.2 Those not covered in this Section are to comply with the relevant requirements of Chapters 1 and 2 of this PART.

7.9.1.3 The bow (including forecastle) side structure strengthening is to comply with the requirements of Section 8 of this Chapter.

### 7.9.2 Longitudinal strength

7.9.2.1 The longitudinal strength is to comply with the requirements of Section 2 of this Chapter.

### 7.9.3 Deck structure

7.9.3.1 The deck structure is to comply with the relevant requirements of Sections 4 and 8, Chapter 2 of this PART.

7.9.3.2 The primary members of the deck structures in the region of container holds are to be verified by direct calculations.

7.9.3.3 The minimum thickness $t_{\min}$ of strength deck is to be calculated by the following formula:

$$t_{\min} = (0.02L + 5.5)\sqrt{K} \quad \text{mm}$$

where: $L$ — length of ship, in m;

$K$ — material factor.

7.9.3.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings is large, two intermediate transition plates are at least to be fitted inside the line of opening. The difference between the thicknesses of adjacent plates, in general not exceeding 1/2 of the thickness of the thicker plate, is to be gradually reduced towards the inside of the line of opening. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

### 7.9.4 Box cross deck structure

7.9.4.1 The box cross deck structure means the transverse box girder structure at the top of transverse bulkheads of container holds.

7.9.4.2 The width and structural scantling of box cross deck structure are to be verified by direct calculations.

7.9.4.3 During the initial design, the width of box cross deck structure may be calculated by the following formula:

$$b = \max(32.5B + 400, 1000) \quad \text{mm}$$

where: $B$ — breadth of ship, in m.

7.9.4.4 In the strength deck plane, the minimum deck thickness of box cross deck structure is to be calculated by the following formula:

$$t = (10 + 0.01L)\sqrt{K} \text{ mm, but not to be less than 12 mm}$$

where: $L$ — length of ship, in m, $L$ need not be taken as greater than 300 m in calculation;

$K$ — material factor.

7.9.4.5 The minimum thickness of bottom plating of box cross deck structure is to be calculated by the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, but not less than 8 mm}$$

where: $s$ — spacing of stiffeners, in m, to be taken not less than 0.95 m in calculation;

$K$ — material factor.

7.9.4.6 The side plating of box cross deck structure (see Figure 7.9.4.6) is to comply with the following requirements:

(1) The thickness $t_1$ of side plating is not to be less than that obtained from the following formula:

$$t_1 = 12s \quad \text{mm, but not less than 10.5 mm}$$

where: $s$ — spacing of stiffeners of side plating, in m.

(2) The thickness $t_2$ of the end insert plate is not to be less than that obtained from the following formula:

$$t_2 = 12s \quad \text{mm, but not less than 14.5 mm}$$

where: $s$ — spacing of stiffeners of side plating, in m.

(3) The minimum scope of end insert plate is calculated by the following formulae:

$$a_1 = 1.75R \quad \text{m}$$

$$a_2 = 0.5b_s \quad \text{m}$$

where: $R$ — radius of the hatch corners of the cargo hatchway opening in the strength deck plane, in m;

$b_s$ — width of double side skin, in m.

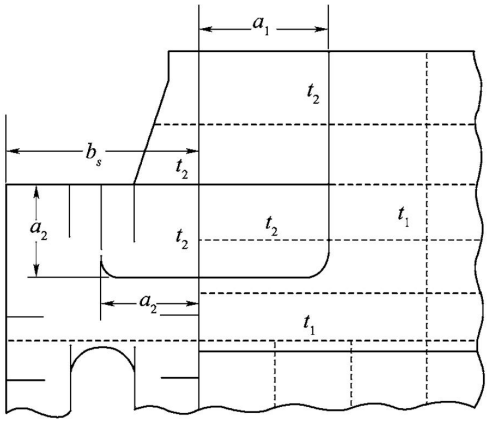



**Figure 7.9.4.6**

### 7.9.5 Strength deck openings

7.9.5.1 The corners of hatchway opening in the strength deck are to be rounded or rounded corners with negative radii. The design of hatch corners is to be verified by direct calculations.

7.9.5.2 For rounded corners near the ship's sides, their radius is not to be less than that obtained from the following formula:

$$R = 0.35 + 0.0005L \quad \text{m}$$

where: $L$ — length of ship, in m.

7.9.5.3 The radius of rounded corners in way of the intersection of deck girders with box cross deck structures is not to be less than 0.25 m.

7.9.5.4 For strength deck, insert plates are required at the hatch corners, generally extending to the extent not less than the requirements of Figure 7.9.5.4. The thickness of insert plates is to be greater than or equal to that of adjacent strength deck. The strengthening of the strength deck at the hatch corners is to be verified by means of fatigue assessment.

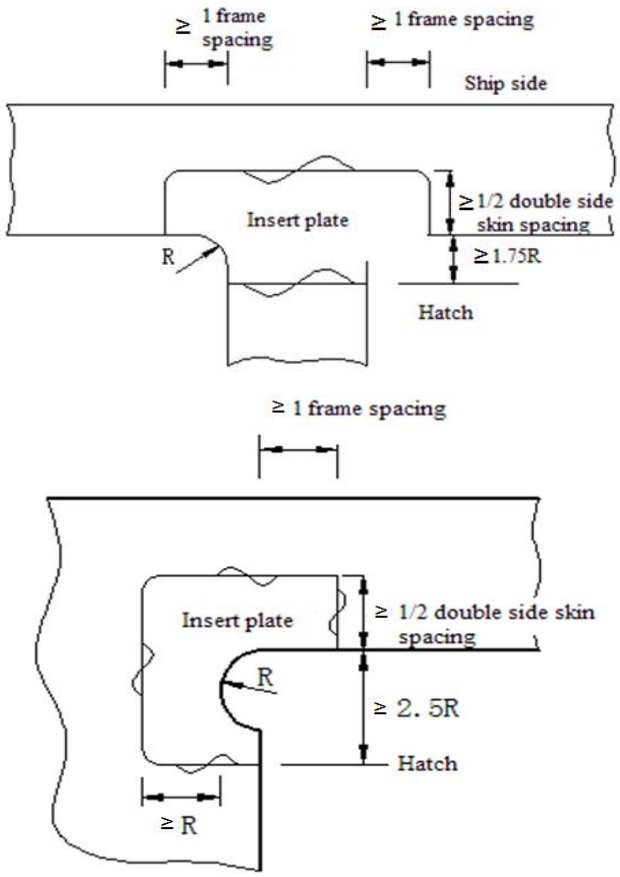



**Figure 7.9.5.4**

7.9.5.5 Large access openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

7.9.5.6 Small openings, such as those for ventilation pipes or scuppers, are to be kept clear of hatch corners, ends of longitudinal hatch coamings, ends of box cross deck structures and other locations of stress concentration.

### 7.9.6 Hatch coamings of container hold

7.9.6.1 The hatch coaming is to be continuous over the entire opening area except for the engine room area. The ends of the coaming are to have an appropriate structural transition.

7.9.6.2 The structure of hatch coaming is to comply with relevant requirements of Section 20 of Chapter 2 of this PART.

7.9.6.3 Hatch coamings are to be provided with brackets spaced not more than 3.15 m apart, and they are also to be provided with face plates. However, the spacing between brackets is not to exceed 6.3 m upon direct strength calculation. The brackets of hatch coamings are to be capable of effectively supporting the face plates. The toe ends of brackets are to terminate at the strength deck longitudinals. Brackets of hatch coamings in way of box cross deck structures are also to comply with 7.9.4.6 of this Section.

7.9.6.4 For face plates of hatch coamings, insert plates are required at the hatch corners, and the scope is shown in Figure 7.9.6.4. The thickness of insert plates is to be greater than or equal to that of adjacent face plates of hatch coamings. The strengthening of face plates of hatch coamings at hatch corners is to be verified by means of fatigue assessment.

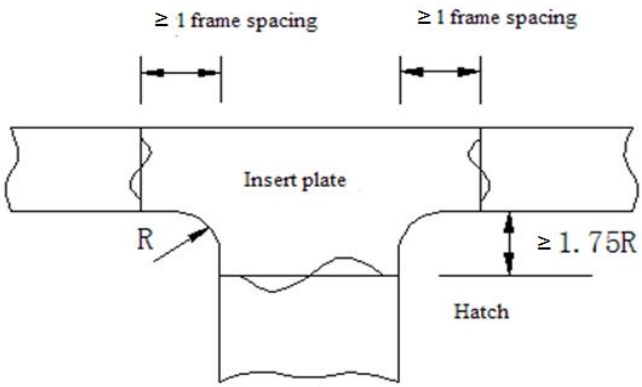



**Figure 7.9.6.4**

### 7.9.7 Shell plating

7.9.7.1 Except where stated by this Section, the shell plating is to comply with relevant requirements of Section 3, Chapter 2 of this PART.

7.9.7.2 In addition to 7.9.7.1 of this Section, the thickness of shell plating is not to be less than that obtained from the following formula:

$$t = \sqrt{LK} \quad \text{mm, but need not be greater than 16 mm}$$

where: $L$ — length of ship, in m;

$K$ — material factor.

7.9.7.3 The difference in thickness between the sheer strake and the adjacent shell plating is in general not to exceed 1/2 of the thickness of the thicker plate. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

### 7.9.8 Structural arrangement of double side skin construction

7.9.8.1 Double side skins are to be fitted throughout the container hold area. The inner skin structure is to extend as far forward and aft as possible and effectively connected with the structures in way with adequate transition arrangements. The supporting members of inner skin are to be fitted in the double side skin, instead of in the container hold.

7.9.8.2 The inner skin is to be of continuous construction, and also maintained continuous in way of the engine room area. The inner skin may be stepped along the ship's length, considering the change of lines and arrangement of container bays. The scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap of inner skin bulkheads having a length of not less than 3 frame spacings for transition.

7.9.8.3 Considering the change of lines and arrangement of container bays, the inner skin may be stepped horizontally in the vertical direction.

7.9.8.4 A transverse ring structure or vertical web is to be provided in line with the transverse watertight bulkheads of container holds in the double side skin. Watertight vertical webs are to be provided as far as practicable below the freeboard deck. Wash bulkheads are to be provided for ballast tanks.

7.9.8.5 A transverse ring structure or vertical web is to be provided in line with the transverse non-watertight pillar bulkheads of container holds in the double side skin.

7.9.8.6 A transverse ring structure or vertical web in the double side skin is to be provided in line with the floors in the double bottom.

7.9.8.7 Manholes are to be provided in vertical webs and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical or along the length of the ship. Except for access openings, the holes on upper and lower adjacent horizontal girders are not to be on the same vertical line. The edge around the holes is to be strengthened.

### 7.9.9 Scantling of double side skin construction

7.9.9.1 The primary members of double side skin construction include side shell platings, vertical transverse webs, horizontal flats, inner skin longitudinal bulkhead platings. The scantling of primary members is to be verified by direct calculations.

7.9.9.2 The inner skin plating is to comply with the following requirements:

(1) The minimum thickness $t$ of inner skin plating is to be calculated by the following formula:

$$t = 7 + 0.02L\sqrt{K} \quad \text{mm}$$

where: $L$ — length of ship, in m, $L$ need not be taken as greater than 300 m in calculation;
$K$ — material factor.

(2) The inner skin plating is to comply with the requirements of 7.9.11.4 of this Section.

(3) The thickness $t$ of inner skin plating forming boundary of tanks within 0.4 $L$ amidships is not to be less than:

$$t = (4 + 0.6\frac{z - z_n}{D - z_n})s\sqrt{hK} + 2.5 \quad \text{mm, above the horizontal neutral axis}$$

$$t = \left(4 + 0.2\frac{z_n - z}{z_n}\right)s\sqrt{F_b hK} + 2.5 \quad \text{mm, below the horizontal neutral axis}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
$D$ — moulded depth, in m;
$Z_n$ — the height of horizontal neutral axis, from base line, of hull cross section, in m;
$Z$ — the height of calculation point from base line, in m;
$F_b$ — reduction factor, see 2.2.5.6, Chapter 2 of this PART;
$K$ — material factor.

(4) The thickness $t$ of inner skin plating forming boundary of tanks is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
$K$ — material factor.

(5) The difference in thickness between the top strake of inner skin and the strake below is in general not to exceed 25 mm, and the maximum difference in thickness is not to exceed 35 mm. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

7.9.9.3 Longitudinals (ship's side, inner skin) are to comply with relevant requirements of Chapter 2 of this PART. The minimum thickness of webs of longitudinals is 10 mm. Longitudinals are to penetrate continuously vertical transverse webs. Where side longitudinals are determined according to 2.7.5.1, Chapter 2 of this PART, the calculated pressure head $h$ is to be obtained from following formulae:

$$h = 0.26C + d - \frac{Z}{D_F}d \quad \text{m, if } Z<D_F$$

$$h = 0.2C + 0.06C\frac{D - Z}{D - D_F} \quad \text{m, if } Z \geq D_F$$

where: $D$ — moulded depth, in m;
$D_F$ — minimum moulded depth, in m, in the middle of ship length, vertical distance from upper edge of flat keel to upper edge of side freeboard deck beam;
$d$ — draught, in m;
$C$ — coefficient, see 2.2.3.1, Chapter 2 of this PART;
$Z$— height of longitudinal to baseline, in m.

7.9.9.4 The thickness $t$ of vertical transverse webs and horizontal flats forming boundary of tank is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
$K$ — material factor.

The minimum thickness of vertical transverse webs and horizontal flats is to be 10 mm. The minimum thickness of watertight flats is 11 mm.

**7.9.10 Double bottom**

7.9.10.1 Except where stated by this Section, the double bottom structure is to comply with the relevant requirements of Section 6, Chapter 2 of this PART.

7.9.10.2 The primary members of double bottom include inner bottom platings, solid floors, girders and bottom platings. The scantlings and arrangements of primary members are to be verified by direct calculations.

7.9.10.3 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or open section structure.

7.9.10.4 The side plates of the duct keel are in general not to be spaced more than 2 m apart; However, where the direct strength assessment has been carried out, the maximum spacing between the side pates are not to be greater than 3 m.

7.9.10.5 Bottom and inner bottom longitudinals are to be fitted within the region of duct keels. The longitudinals are to be maintained continuous. The bottom longitudinals at the center line of the ship are to be suitably increased in scantling.

7.9.10.6 A strength frame ring is to be provided to the duct keel in the plane of solid floors and the middle of spacing of solid floors. For transverse girders of inner bottom in the strength frame ring, their section modulus is not to be less than 85% of those of ship's bottom. The section modulus $W$ of transverse girders of ship's bottom is not to be less than that obtained from the following formula:

$$W = 10.6Sdl^2K \qquad \text{cm}^3$$

where: $S$ — spacing of the strength frame ring, in m;
$d$ — draught, in m, to be taken not less than 0.66 times the vertical distance from the ship's bottom to the freeboard deck;
$l$ — span, in m, to be taken as the spacing between two side plates;
$K$ — material factor.

7.9.10.7 At least three side girders spaced apart generally not more than 3.5 m are to be fitted on each side of the centreline. Forward of 0.2$L$ from the F.P., the spacing of side girders is not to be greater than 4 longitudinal spaces. Side girders are to be equally spaced and extend forward and aft as far as practicable.

7.9.10.8 Side girders are to be arranged and local stiffening is to be required under container corner seatings.

7.9.10.9 Solid floors in the region of container holds are to comply with the following requirements:

(1) Solid floors are to be fitted under transverse watertight bulkheads, transverse non-watertight pillar bulkheads/mid-hold supports, under container corners at hold quarter length locations and at other locations. Solid floors are in general to be spaced not more than 3.6 m apart.

(2) The thickness $t$ of solid floors is to comply with relevant requirements of Section 6 of this Chapter and not to be less than that obtained from the following formula:

$$t = 10s\sqrt{\frac{R_{eH}}{235}} + 2.5 \qquad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$R_{eH}$ — yield stress of the material, in N/mm$^2$.

(3) In addition to complying with the requirements of (2) of this paragraph, the thickness $t$ of watertight floors is to comply with relevant requirements of Section 6 of this Chapter.

7.9.10.10 The thickness $t$ of inner bottom plating of container holds is not to be less than that obtained from the following formula:

$$t = 1.36(s + 0.66)\sqrt[4]{LdK^2} \qquad \text{mm}$$

where: $L$ — length of ship, in m;
$d$ — draught, in m;
$s$ — spacing of longitudinals, in m;
$K$ — material factor.

The thickness $t$ of inner bottom plating of container holds forming boundary of tanks is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

7.9.10.11 The section modulus $W$ of inner bottom longitudinals of container holds is not to be less than that obtained from the following formula:

$$W = \frac{9.54dsl^2K}{2.1 - F_b} \qquad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$l$ — span of longitudinals, in m;
$d$ — draught, in m;

$F_b$ — reduction factor at calculation point;

$K$ — material factor.

7.9.10.12 Strengthening of bottom forward is to comply with the relevant requirements of 2.15.3 of Section 15, Chapter 2 of this PART. In the strengthening region, for the strengthening of double bottom framed longitudinally, 2.15.3.3(1) of Section 15, Chapter 2 of this PART may not be required, but the spacing of plate floors is not to exceed 3.2 m or 4 times the spacing of longitudinals (whichever is the greater).

7.9.10.13 The thickness of center girders and side girders in region of container holds and the arrangement of supporting bracket of center girders are to comply with relevant requirements of Section 6 of this Chapter.

### 7.9.11 Transverse bulkhead of container hold

7.9.11.1 The primary members of transverse bulkhead include bulkhead platings, vertical webs and horizontal girders. The scantling of primary members is to be verified by direct calculations.

7.9.11.2 The web thickness $t$ of girders of transverse bulkhead is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{\frac{R_{eH}}{235}} + 0.5 \quad \text{mm , and not less than 9 mm}$$

where: $s$ — spacing of web stiffeners, in m;

$R_{eH}$ — yield stress of the material, in N/mm$^2$.

7.9.11.3 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively.

7.9.11.4 The scantlings of watertight transverse bulkhead platings and stiffeners are to be determined in accordance with the requirements of Section 12, Chapter 2 of this PART. The design head $h$ is to be determined in accordance with the following requirements:

(1) For watertight transverse bulkhead platings, the design head $h$ is to be determined in accordance with the following requirements (whichever is the greatest):

① vertical distance measured from the lower edge of the plate in a strake to the deepest equilibrium waterline obtained from the applicable damage stability calculations;

② vertical distance measured from the lower edge of the plate in a strake to the freeboard deck;

③ 2.5 m.

(2) For stiffeners, the design head $h$ is to be determined in accordance with the following requirements (whichever is the greatest):

① vertical distance measured from the mid-span of stiffeners to the deepest equilibrium waterline obtained from the applicable damage stability calculations;

② vertical distance measured from the mid-span of stiffeners to the freeboard deck;

③ 2 m.

7.9.11.5 The minimum thickness of watertight transverse bulkhead platings is 8 mm.

7.9.11.6 One non-watertight transverse pillar bulkhead is to be fitted at every two 20 feet container bays along the ship's length in the container hold. The non-watertight transverse pillar bulkhead generally consists of vertical webs and horizontal girders.

### 7.9.12 Design verification

7.9.12.1 Except where otherwise stated, the design verification is not to lower the requirements for hull structures of this Section. The design verification of hull structures includes:

(1) direct calculation of strength assessment;

(2) fatigue strength assessment.

7.9.12.2 Direct calculations are to be carried out for strength assessment of the whole ship, primary structures of cargo holds and local structure of deck hatch corner under specified loads in accordance with Appendix 2 of this Chapter.

7.9.12.3 Fatigue strength assessment is to be carried out to the container hold structures in accordance with CCS Guidelines for Fatigue Strength of Ship Structure.

# Section 10 LONGITUDINAL STRENGTH OF COMBINED BENDING AND TORSIONAL MOMENTS FOR SHIPS WITH LARGE OPENINGS

### 7.10.1 General requirements

7.10.1.1 For ships with large openings on deck, the longitudinal strength of combined bending and torsional moments is to be checked by the following:

(1) for length $L \leq 250$ m, the method defined in this Section or the method defined in (2);

(2) for length $L > 250$ m, the direct strength calculation of whole ship defined in Appendix 2;

7.10.1.2 Stresses are to be calculated for at least seven transverse sections in the cargo area as follows:

(1) at the forward end of the engine room;

(2) at the forward end of the opening length, opening length being the distance from the aft end of the cargo hatch before the engine room to the forward end of the foremost cargo hatch;

(3) at five intermediate sections within the opening length, at least three of which are to be within 0.4$L$ amidships. The intermediate sections are to be arranged as far as possible in way of abrupt changes of longitudinal structures.

7.10.1.3 In addition, the stresses at transverse sections in way of abrupt changes of any other longitudinal structures beyond the requirements of 7.10.1.2 of this Section are to be calculated.

### 7.10.2 Wave bending moment

7.10.2.1 The vertical wave bending moment $M_v$ is to be calculated by the following formula:

$$M_v = 9.81MKFL^2B(C_b + 0.7)\times 10^{-2} \quad \text{kN·m}$$

where: $L$ — length of ship, in m;

$B$ — breadth of ship, in m;

$M$ — distribution factor of bending moment, see 2.2.3.1 of Section 2, Chapter 2 of this PART;

$C_b$ — block coefficient, taken as 0.6 for actual $C_b$ less than 0.6;

$$K = 4.47(\frac{L}{1000} - 0.230)^2 + 0.817$$

$F$—factor, obtained from the following formulae:

$F = 9.4 - 0.95(\frac{300 - \mathrm{L}}{100})^{3/2}$, for $L \leq 300$ m;

$F = 9.4$, for $300 < L < 350$ m;

$F = 9.4 - 0.45(\frac{\mathrm{L} - 350}{100})^{3/2}$, for $350 \leq L \leq 500$ m.

7.10.2.2 The midship horizontal wave bending moment $M_H$ is to be calculated by the following formula:

$$M_H = 0.431L^2B \quad \text{kN·m}$$

where: $L$, $B$ — see 7.10.2.1 of this Section.

$M_H$ is equal to zero at ends, and the distribution of $M_H$ along the length of the ship is to follow a straight line.

### 7.10.3 Torque

7.10.3.1 The hydrodynamic torque $M_T(x)$ at any cross section along the length of the ship is to be calculated by the following formula:

$$M_T(x) = 9.81e^{-0.00295L}\frac{LB^3C_T}{20000}(1.75 + 1.5\frac{\varepsilon}{D})(1 - \cos\frac{2\pi}{L}x) \quad \text{kN·m}$$

where: $e$ — base of natural logarithms;

$L$ — length of ship, in m;

$B$ — breadth of ship, in m;

$D$ — moulded depth, in m;

$C_T = 13.2 - 43.4C_W + 78.9{C_W}^2$;

where: $C_w$ — the water plane area coefficient, need not be greater than $0.165 + 0.95C_b$;

$\varepsilon$ — the distance measured from the shear centre below the baseline of the ship to the baseline, in m;

$x$ — distance from any one cross-section to A.P., in m;

$C_b$ — block coefficient, see 7.10.2.1 of this Section.

7.10.3.2 Cargo torque is caused by the uneven transverse distribution of cargoes, consumables or ballast. Unless any other loading case is specified, the cargo torque $M_{TC}$ amidships is to be calculated by the following formula:

$$M_{TC} = 15.7Bn_Bn_t \quad \text{kN·m}$$

where: $B$ — breadth of ship, in m;

$n_B$ — number of stacks of containers in cargo holds amidships along the breadth of ship;

$n_t$ — number of tiers of containers in cargo holds amidships, excluding the containers on deck and on hatch covers.

$M_{TC}$ is equal to zero at ends and the distribution of $M_{TC}$ along the length of the ship is to follow a straight line.

### 7.10.4 Stress calculation and criteria

7.10.4.1 The still water bending stresses $\sigma_s$ is to be calculated by the following formula:

$$\sigma_s = \frac{M_s}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: $M_s$ — permissible still water bending moment, in kN·m;

$W_V$ — vertical bending section modulus at deck or bottom, in cm³, to be calculated in accordance with the relevant requirements of Section 2, Chapter 2 of this PART.

The permissible still water bending stress $[\sigma_s]$ at strength deck and keel is $88/K$, in N/mm², where $K$ is material factor.

7.10.4.2 The combined vertical bending stress $\sigma_c$ for ships under the heading wave condition is to be calculated by the following formula:

$$\sigma_c = \frac{M_s + M_V}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: $M_s$, $W_v$ — same as defined in 7.10.4.1 of this Section;

$M_V$ — vertical wave bending moment, in kN·m, see 7.10.2.1 of this Section.

The permissible combined vertical bending stress $[\sigma_c]$ is $157/K$ at the strength deck, in N/mm² and $150/K$ at the keel, in N/mm², where $K$ is referred to 7.10.4.1.

7.10.4.3 The combined stress for ships under the oblique sea condition is to be the sum of the following stresses:

(1) The combined vertical bending stress $\sigma_c$ is to be determined by the following formula:

$$\sigma_c = \frac{M_s + 0.6M_V}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: $M_s$, $W_v$ — same as defined in 7.10.4.1 of this Section;

$M_V$ — see 7.10.2.1 of this Section.

(2) The horizontal bending stress $\sigma_H$ is to be determined by the following formula:

$$\sigma_H = \frac{yM_H}{I_H} \times 10^5 \quad \text{N/mm}^2$$

where: $M_H$ — horizontal wave bending moment, in kN·m, see 7.10.2.2 of this Section;

$y$ — horizontal distance from the point under consideration to centreline of the transverse section, in m;

$I_H$ — horizontal moment of inertia, in cm⁴.

(3) The warping stress due to the hydrodynamic torque $M_T$ and cargo torque $M_{TC}$.

The permissible combined stresses at strength deck and bottom is $157/K$, in N/mm², where $K$ is referred to 7.10.4.1.

# Appendix 1 CONTAINER SECURING

## 1 General Requirements

### 1.1 Application

1.1.1 Container stowage and securing requirements in this Appendix are based on containers manufactured in compliance with ISO 1496-1:2013.

This Appendix sets forth the survey requirements for the initial installation of container securing systems aboard vessels. It is to be clearly understood that no representation is made as to the ability of any container to withstand the loads allowed. The allowable loads have been derived from successful usage over a number of years and may exceed the design loads set forth in ISO Standard. It is the responsibility of the shipowner, or operator to ascertain that the containers used in the system can withstand the loads applied to them.

1.1.2 External dimensions, rated weights and corner fitting locations for common freight containers are given in Table 1.1.2.

**External Dimensions, Rated Weights and Corner Fitting Locations for Common Freight Containers①**

**Table 1.1.2**

| Nominal Size | Container Designation | Length (mm) | Width (mm) | Height (mm) | Dimensions Center to Center of Corner Fittings(longitudinal) (mm) | Dimensions Center to Center of Corner Fittings(transverse)(mm) | Rated Weight (kg) |
|---|---|---|---|---|---|---|---|
| 20 ft ISO668 | 1CC | 6058 | 2438 | 2591 | 5853 | 2259 | 30480 (24000)② |
| | 1C | | | 2438 | | | |
| | 1CX | | | <2438 | | | |
| 40 ft ISO668 | 1AAA | 12192 | 2438 | 2896 | 11985 | 2259 | 30480 |
| | 1AA | | | 2591 | | | |
| | 1A | | | 2438 | | | |
| | 1AX | | | <2438 | | | |
| 45 ft ISO668 | 1EEE | 13716 | 2438 | 2896 | 11985 13509 | 2259 | 30480 |
| | 1EE | | | 2591 | | | |
| 43 ft | | 13103 | 2438 | 2591 | 11985 | 2259 | 30480 |
| 48 ft | | 14630 | 2591 | 2908 | 11985 14422 | 2259 | 30480 |
| 53 ft | | 16154 | 2591 | 2908 | 11985 15947 | 2259 | 30480 |

Notes: ① The statistics of containers of ISO standard in the Table are determined according to ISO 668:2013.

② The rated weight for containers of 20 ft manufactured in accordance with the previous version of Amd 1:2005 of ISO 668:1995 is 24,000 kg. In the design of securing system, the recommended weights of empty containers are as follows:

| | |
|---|---|
| 20 ft container | 2.5 t |
| 40 ft container | 3.5 t |
| 43 ft and 45 ft container | 4.0 t |
| 48 ft and 53 ft container | 4.5 t |

### 1.2 Other provisions

1.2.1 For ships other than container ships, container securing arrangements are to comply with the requirements of 1 to 5 of this Appendix.

### 1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval:

(1) General arrangement plan showing the disposition and design weights of the containers;

(2) Details of the cell guide structure, where fitted;

(3) Plans of lashing bridges, where fitted;

(4) Plans of stanchions on the deck, where fitted;

(5) Plans of securing arrangements of containers not associated with cell guides, where fitted;

(6) Details of securing devices (fixed and portable equipment, including safe working load);

(7) Arrangement plan of fixed securing devices and plan of hull supporting structure;

(8) Container securing manual/arrangement plan (approved container securing manual/arrangement plan is

to be kept on board).

### 1.4 Limitation on ship handling

Improper ship handling related to course and speed or threshold phenomena like parametric rolling can create adverse loads acting on the ship and the cargo which are in excess of the loads determined on the basis of 4 of this Appendix. It is the responsibility of the master to apply good seamanship in order to mitigate excessive ship motions to reduce loads acting on the cargo stowage arrangements.

### 1.5 Definitions

1.5.1 **Bay**: An indication of the longitudinal position of a stack on ship. An athwartship block of containers associated with a hatch or hatch cover containing multiple stacks (or rows).

1.5.2 **Cell Guides**: A rigid securing system of vertical steel angles, spaced with some margin on container length and width that provides alignment and horizontal restraint for container stacks.

1.5.3 **Container Block**: A number of container stacks interconnected by double cones and/or bridge fittings.

1.5.4 **Container Stac**k: A single vertical stack of containers which may be secured by lock fittings, lock fittings plus lashings, or cell guides.

1.5.5 **Corner Fittin**g: A fixture, typically a casting, consisting of standard apertures and faces, which provide a common interface for handling and securing containers. It is an integral part of the container end frame structure and is generally in compliance with ISO Standard 1161. A similar fitting can also be found at intermediate posts located some distance from the end frame structure (such as at the 40-ft location on a 45-ft container).

1.5.6 **Corner Post**: Reinforced vertical structure between the corner fittings at the ends of containers designed to take the compressive and tensile forces exerted by lifting, stacking, and securing. Some containers also have intermediate 'corner' posts located some distance in from their ends at a nominal 40-ft spacing.

1.5.7 **Design Breaking Load**: The design breaking load of a component is determined by prototype testing. The design breaking load is not to be more than the last load recorded during the test prior to failure.

1.5.8 **Design GM Value**: The *GM* values used in the lashing calculations of containers are determined by the designer and specified in the container securing manual/arrangement plan. At least the minimum value and the maximum value are to be included. The minimum value is not to be less than the *GM* value in the condition where the maximum number of containers is loaded and the maximum value is not to be less than the maximum value of all expected container loading conditions. In the initial design, the minimum design *GM* value may be taken as 0.025*B*, and the maximum design *GM* value may be taken as 0.075*B,* where *B* is the breadth of the ship.

1.5.9 **ISO Freight Container**: Containers meeting the design dimensions and rated weights of ISO container standards such as:

ISO 1496-1 Series 1 freight containers
ISO 668 External dimensions and ratings
ISO 1161 Corner fittings and specifications

1.5.10 **Lashing Assembly**: A tension element made-up of a rod, wire rope or chain, a tensioning device, and a lashing point; used to secure a stack of containers.

1.5.11 **Lashing Point**: Fittings welded to the deck, hatch cover, stanchion, and lashing bridge, connecting lashing devices to the vessel structure or hatch covers. These include D-rings, lashing eyes plates, etc.

1.5.12 **Lashing Bridge**: An athwartship, elevated platform on deck from which container stacks on the hatch covers or deck may be secured with lashing assemblies.

1.5.13 **Safe Working Load (SWL)**: The SWL of a securing device is the design breaking load divided by an appropriate safety factor. The maximum resultant load upon a component is not to exceed the SWL.

1.5.14 **Proof Load**: A test load applied to a container securing device during production testing. The minimum proof load is to be determined according to Table 2.2.1.

1.5.15 **Row/Stack**: An indication of the transverse position of a container in a stack.

1.5.16 **Racking**: Distortion of the container end or side due to horizontal forces.

1.5.17 **Securing Devices**: The general name of all fixed and portable devices used to secure and support containers.

1.5.18 **Tier**: An indication of the vertical position of a container in a stack. The first tier is the lowest position in the stack.

1.5.19 **Turnbuckle**: A specific type of Tensioning Device, used to connect the lashing rod and the lashing point.

1.5.20 **Twist lock**: A fitting inserted into corner fittings and used to secure containers stacked on top of each other in tension, compression, and shear.

### 1.6 Special Requirements

1.6.1 For containers not covered by ISO Standard 1496-1 as well as special ways of containers arrangement, the securing of such containers is to be considered according to the parameters and allowable loads as specified in 4.8 of this Appendix.

## 2 Materials and Testing

### 2.1 Materials

2.1.1 Steels used for the construction of the cell guides and the fixed securing devices attached to the hull are to comply with the relevant requirements of CCS Rules for Materials and Welding.

### 2.2 Prototype testing

2.2.1 Except for cell guides, prototype tests are to be carried out to determine the breaking loads of securing devices. The testing is to be carried out on at least two randomly selected samples of each item. The relationship between design breaking load and safe working load is to be as indicated in Table 2.2.1. No permanent deformation (other than that due to initial embedding of component parts) is to be induced by test loads up to the proof load given in the Table.

**Design Breaking Loads and Proof Loads**

**Table 2.2.1**

| Item | Min. design breaking load (kN) | | Min. proof load (kN) | |
|---|---|---|---|---|
| | $SWL \leq 400$ | $SWL > 400$ | $SWL \leq 400$ | $SWL > 400$ |
| Lashings: | | | | |
| Wire rope | $3 \times SWL$ | | | |
| Rod (higher tensile steel) | $2 \times SWL$ | | $1.5 \times SWL$ | |
| Chain (mild steel) | $3 \times SWL$ | | | |
| Chain (higher tensile steel) | $2.5 \times SWL$ | | | |
| Other securing devices | $2 \times SWL$ | $SWL + 400$ | $1.5 \times SWL$ | SWL + 200 |

Notes: ① The yield stress of higher tensile steel is not to be less than 315 N/mm$^2$.

② Breaking and proof loads for lashings of material other than steel will be specially considered.

③ *SWL* means the safe working load, in kN.

2.2.2 Where one of the two test samples fails before the design breaking load is reached, an additional sample is to be tested. The prototype testing may be accepted provided that the following conditions are met:

(1) The failure load is not less than 95% of the design breaking load;

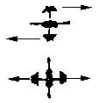
(2) An additional sample is tested satisfactorily;

(3) The average failure load of the three samples, taking the additional sample into account, is not less than the design breaking load.

2.2.3 Securing devices may be tested in accordance with Table 2.2.3.

**Test Mode**

**Table 2.2.3**

| Securing device | Test mode | Recommended minimum value (kN) | | |
|---|---|---|---|---|
| | | *SWL* | Proof load | Breaking load |
| Lashing rod (higher tensile steel) |  | 180 | 270 | 360 |
| Lashing rod | | 250 | 375 | 500 |
| Lashing chain (higher tensile steel) | | 80 | — | 200 |
| Lashing chain | | 100 | — | 300 |
| Lashing wire | | 120 | — | 360 |
| Turnbuckle |  | 250 | 375 | 500 |
| Twist lock |  | 200 | 300 | 400 |
| | | 250 | 375 | 500 |
| Cone |  | 200 | 300 | 400 |
| Embedded stacking device |  | 250 | 375 | 500 |
| Stacking device |  | 250 | 375 | 500 |
| |  | 200 | 300 | 400 |
| D-ring |  | 250 | 375 | 500 |
| Lashing eye plate |  | 250 | 375 | 500 |
| Buttress |  | *SWL* is to be the individual calculation result of the stowage arrangement and test load is to be determined according to Table 2.2.1. | | |

## 2.3 Product testing

2.3.1 For production by a manufacturer in batches according to the plans and documents of the securing devices which have been accepted in the prototype testing, such products are to be subjected to testing according to one of the following requirements.

(1) Batch testing: For securing devices except for chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be proof loaded to 1.5 times the safe working load. For chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be tested to breaking.

(2) Individual testing: Every securing device is to be proof loaded to the safe working load of the item. In addition, one randomly selected sample from every batch of chain or wire rope lashings is to be tested to breaking prior to delivery.

2.3.2 For production test carried out in accordance with 2.3.1(1) of this Appendix, permanent deformation will not be accepted within the range of loading up to:

(1) 1.5 × *SWL*, where *SWL* < 250 kN;

(2) *SWL* + 125, where *SWL* ≥ 250 kN.

2.3.3 In the event of premature failure or serious plastic deformation occurring in a test sample, two further samples are to be selected for testing. In the event that these samples are found to be satisfactory, the associated batch may be accepted.

2.3.4 For production test carried out in accordance with 2.3.1(2) of this Appendix, permanent deformation will not be accepted.

## 3 Stowage and Securing of Containers

### 3.1 General requirements

3.1.1 Containers are to be secured by one, or a combination of the following systems: corner locking devices, lashings, cell guides, buttresses, shores or equivalent structural restraint.

3.1.2 The method of securing containers is to be determined by calculating the forces acting on the containers in accordance with 4 of this Appendix and is to be capable of ensuring the strength of containers and securing devices.

### 3.2 Arrangements for stowage and securing on exposed decks

3.2.1 The stowage of containers on exposed decks is to satisfy the following requirements.

(1) The arrangements are to be such as to permit safe access for personnel in the necessary working of the ship, and to provide sufficient access for installation and inspection of the securing devices.

(2) Containers stowed on deck or on hatch covers are generally to be aligned in the fore and after direction.

(3) Containers are to be stowed so that they do not extend beyond the ship's side; adequate support is to be provided where they overhang hatch coamings or other deck structures.

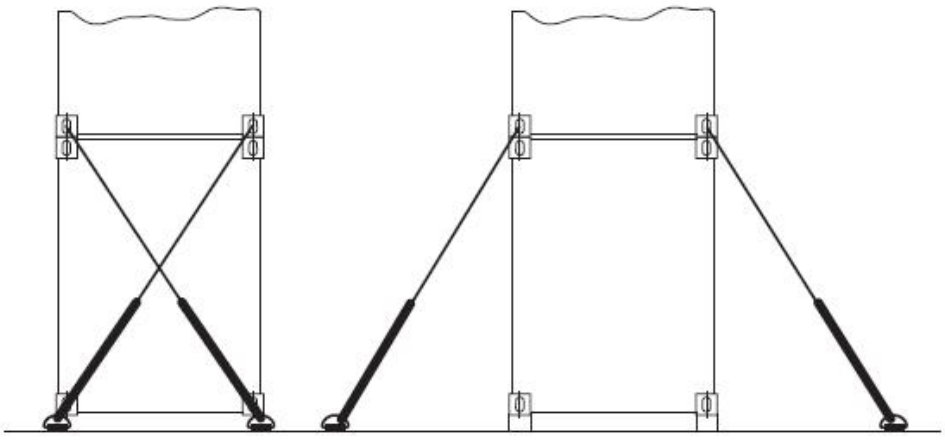
(4) Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent.

3.2.2 The securing for containers stowed on the exposed deck is to comply with the following requirements:

(1) Twist locks and/or lashing arrangements are to be used for securing containers.

(2) In order to improve the lashing efficiency, the fixed lashing points can be arranged on the lashing bridge. In such case, the relative displacement between the structure of lashing bridge and the container stack is to be considered for calculating the lashing force.

(3) Normally, the internal lashing type is to be used for securing, as shown in Figure 3.2.2(a). For the external lashing type as shown in Figure 3.2.2(b), when the corner fitting connected to the lashing rod is in tension, due to the clearance existing between the twist locks and the container corner fittings, the twist locks will not be subject to the pulling force until such clearance between the twist lock and corner fitting of container is closed. In such case, the lashing rod may be broken as a result of excessive pulling force. When the external lashing type is selected, this situation is to be considered in securing calculation. Where no actual data is available, 12 mm vertical clearance is to be considered for semi-automatic twist lock and 20 mm vertical clearance for automatic twist lock.



(a) Internal lashing (b) External lashing

**Figure 3.2.2 Internal lashing and external lashing**

3.2.3 Cell guides may be used.

3.2.4 Up to a calculated remaining lifting force of 375 kN a vertical lashing can be applied for securing containers.

### 3.3 Arrangements for stowage and securing in holds

3.3.1 Without cell guides

(1) Containers are generally to be stowed in holds and 'tween decks in the fore and after direction.

(2) Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shores or lashings, and the method of securing may be referred to 3.2 of this Appendix.
(3) Where the calculations indicate that remaining lifting forces could occur at any particular level, twist locks are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.
(4) Where the calculations indicate that remaining lifting forces will not occur between containers at any level, consideration will be given to the use of double stacking cones in lieu of locking devices throughout.
(5) Buttresses are to be securely attached to the ship's structure. Where practicable, the attachment to the ship's structure is to include means for vertical adjustment of the buttresses to match container stacks of different heights.
(6) Shores of the compression type only may be permanently attached to the ship's structure or they may be hinged or portable and the ship's structure in way is to be reinforced as necessary. The shores are to abut the container corner fittings with minimal clearance.
(7) Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads, and the fittings used for these linkages are to be of adequate strength as buttresses or shores.
(8) The ship's structure supporting shores and buttresses is to be reinforced as necessary.

3.3.2 Using cell guides

(1) The cell guides are not to form an integral part of the ship's structure; the guide system is to be so designed as to keep it free from the main hull stresses.
(2) Cell guides are to be of robust construction; they are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure. The thickness of guides is not to be less than 12 mm.
The allowable stresses of cell guides are to be as follows ($R_{eH}$ being the yield stress of the material, in N/mm$^2$):

Allowable shear stress: $[\tau] = 0.4R_{eH}$
Allowable normal stress: $[\sigma] = 0.67R_{eH}$

(3) Cell guides are generally to be fabricated from steel plate and rolled sections; the guides are to be adequately supported at their upper ends.
(4) Athwartship cross ties are to be fitted between cell guides as a spacing determined from the loading on the guides but, generally, not more than 5 m apart. Wherever possible, cross ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and after movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and after deflection in the cross tie can be shown not to exceed 20 mm, then one support point may be accepted.
(5) The intersection between cell guide and cross ties is to provide adequate torsional stability.
(6) Intermediate brackets are to be fitted to vertical cell guides at suitable intervals.
(7) Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted, they are to comply with the requirements for spacing and deflection as specified in 3.3.2(4) of this Appendix.
(8) Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.
(9) The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. Attention is to be given to the accuracy in fitting cell guides so as to ensure smooth loading and unloading of containers.
(10) A device to pre-centre the container and direct it into the cell guides is to be of robust construction, and is normally to be fitted at the top of the guide bars.
(11) Where containers of different height are stacked in the cargo holds, the horizontal force acting at the middle of each two cross ties needs to be considered for the strength of guides.

## 3.4 Mixed stacks of 20 ft and 40 ft containers

3.4.1 Where the cell guides are arranged for the carriage of 40 ft containers, provision may be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.
3.4.2 Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers will be considered.
3.4.3 Where it is desired to stow 20 ft containers in the lower tiers without external support at the mid-bay location, the following requirements are to be complied with.
(1) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with no 40 ft container overstowed can be derived from Tables 3.4.3(1) depending on the acceleration and the number of tiers in the stack.

(2) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed can be derived from Table 3.4.3(2) depending on the acceleration and the number of tiers in the stack.
(3) Racking forces acting on end walls of 20 ft containers stowed in the lowest tier at the mid-length of a cell arranged for 40 ft containers are not to exceed 185 kN. The orientation of the containers is to ensure as far as possible that all door ends or closed ends are facing in one direction. Weights listed in Table 3.4.3(1) and Table 3.4.3(2) apply to 20 ft containers the maximum rated weight of which is 30,480 kg.
(4) Stacking cones are to be fitted between each tier of the 20 ft containers and between the 20 ft containers and bottom of the hold to prevent transverse sliding.
(5) Where fore and aft tension/pressure adapter cones are used to link two 20 ft containers to equate to a 40 ft container, the storage of 40 ft containers above is not required.

**Stowage Weights of 20 ft Containers (t)**

**Table 3.4.3(1)**

| $a_t$ (g) / tiers | 0.30 | 0.31 | 0.32 | 0.33 | 0.34 | 0.35 | 0.36 | 0.37 | 0.38 | 0.39 | 0.40 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 168.9 | 163.5 | 158.4 | 153.6 | 149.1 | 144.8 | 140.8 | 137.0 | 133.4 | 129.9 | 126.7 |
| 11 | 168.8 | 163.4 | 158.2 | 153.5 | 148.9 | 144.7 | 140.7 | 136.9 | 133.3 | 129.8 | 126.6 |
| 10 | 168.4 | 163.0 | 157.9 | 153.1 | 148.6 | 144.3 | 140.3 | 136.5 | 133.0 | 129.5 | 126.3 |
| 9 | 167.4 | 162.0 | 156.9 | 152.2 | 147.7 | 143.5 | 139.5 | 135.7 | 132.1 | 128.8 | 125.5 |
| 8 | 166.7 | 161.3 | 156.3 | 151.5 | 147.1 | 142.9 | 138.9 | 135.1 | 131.6 | 128.2 | 125.0 |
| 7 | 166.4 | 161.0 | 156.0 | 151.3 | 146.8 | 142.6 | 138.7 | 134.9 | 131.4 | 128.0 | 124.8 |
| 6 | 164.8 | 159.5 | 154.5 | 149.8 | 145.4 | 141.2 | 137.3 | 133.6 | 130.1 | 126.7 | 123.6 |
| 5 | 152.5 | 152.5 | 152.5 | 149.3 | 144.9 | 140.8 | 136.9 | 133.2 | 129.7 | 126.4 | 123.2 |
| 4 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 121.5 |
| 3 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |

| $a_t$ (g) / tiers | 0.41 | 0.42 | 0.43 | 0.44 | 0.45 | 0.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 123.6 | 120.7 | 117.9 | 115.2 | 112.6 | 110.2 | 107.8 | 105.6 | 103.4 | 101.4 | 99.4 |
| 11 | 123.5 | 120.6 | 117.8 | 115.1 | 112.5 | 110.1 | 107.7 | 105.5 | 103.3 | 101.3 | 99.3 |
| 10 | 123.2 | 120.3 | 117.5 | 114.8 | 112.3 | 109.8 | 107.5 | 105.3 | 103.1 | 101.0 | 99.1 |
| 9 | 122.5 | 119.6 | 116.8 | 114.1 | 111.6 | 109.2 | 106.8 | 104.6 | 102.5 | 100.4 | 98.5 |
| 8 | 122.0 | 119.1 | 116.3 | 113.6 | 111.1 | 108.7 | 106.4 | 104.2 | 102.0 | 100.0 | 98.0 |
| 7 | 121.8 | 118.9 | 116.1 | 113.5 | 110.9 | 108.5 | 106.2 | 104.0 | 101.9 | 99.8 | 97.9 |
| 6 | 120.6 | 117.7 | 115.0 | 112.3 | 109.8 | 107.5 | 105.2 | 103.0 | 100.9 | 98.9 | 96.9 |
| 5 | 120.2 | 117.3 | 114.6 | 112.0 | 109.5 | 107.1 | 104.8 | 102.7 | 100.6 | 98.6 | 96.6 |
| 4 | 118.5 | 115.7 | 113.0 | 110.4 | 108.0 | 105.6 | 103.4 | 101.2 | 99.2 | 97.2 | 95.3 |
| 3 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |

| $a_t$ (g) / tiers | 0.52 | 0.53 | 0.54 | 0.55 | 0.56 | 0.57 | 0.58 | 0.59 | 0.60 | 0.61 | 0.62 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 97.5 | 95.6 | 93.8 | 92.1 | 90.5 | 88.9 | 87.4 | 85.9 | 84.5 | 83.1 | 81.7 |
| 11 | 97.4 | 95.5 | 93.8 | 92.1 | 90.4 | 88.8 | 87.3 | 85.8 | 84.4 | 83.0 | 81.7 |
| 10 | 97.2 | 95.3 | 93.6 | 91.9 | 90.2 | 88.6 | 87.1 | 85.6 | 84.2 | 82.8 | 81.5 |
| 9 | 96.6 | 94.7 | 93.0 | 91.3 | 89.7 | 88.1 | 86.6 | 85.1 | 83.7 | 82.3 | 81.0 |
| 8 | 96.2 | 94.3 | 92.6 | 90.9 | 89.3 | 87.7 | 86.2 | 84.7 | 83.3 | 82.0 | 80.6 |
| 7 | 96.0 | 94.2 | 92.4 | 90.8 | 89.1 | 87.6 | 86.1 | 84.6 | 83.2 | 81.8 | 80.5 |
| 6 | 95.1 | 93.3 | 91.5 | 89.9 | 88.3 | 86.7 | 85.2 | 83.8 | 82.4 | 81.0 | 79.7 |
| 5 | 94.8 | 93.0 | 91.3 | 89.6 | 88.0 | 86.5 | 85.0 | 83.5 | 82.1 | 80.8 | 79.5 |
| 4 | 93.4 | 91.7 | 90.0 | 88.3 | 86.8 | 85.2 | 83.8 | 82.4 | 81.0 | 79.7 | 78.4 |
| 3 | 91.5 | 89.8 | 88.2 | 86.6 | 85.0 | 83.5 | 82.1 | 80.7 | 79.4 | 78.1 | 76.8 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |

| $a_t$ (g) / tiers | 0.63 | 0.64 | 0.65 | 0.66 | 0.67 | 0.68 | 0.69 | 0.70 | 0.71 | 0.72 | 0.73 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 80.4 | 79.2 | 78.0 | 76.8 | 75.6 | 74.5 | 73.4 | 72.4 | 71.4 | 70.4 | 69.4 |
| 11 | 80.4 | 79.1 | 77.9 | 76.7 | 75.6 | 74.5 | 73.4 | 72.3 | 71.3 | 70.3 | 69.4 |
| 10 | 80.2 | 78.9 | 77.7 | 76.5 | 75.4 | 74.3 | 73.2 | 72.2 | 71.2 | 70.2 | 69.2 |
| 9 | 79.7 | 78.5 | 77.3 | 76.1 | 74.9 | 73.8 | 72.8 | 71.7 | 70.7 | 69.7 | 68.8 |
| 8 | 79.4 | 78.1 | 76.9 | 75.8 | 74.6 | 73.5 | 72.5 | 71.4 | 70.4 | 69.4 | 68.5 |
| 7 | 79.2 | 78.0 | 76.8 | 75.6 | 74.5 | 73.4 | 72.3 | 71.3 | 70.3 | 69.3 | 68.4 |
| 6 | 78.5 | 77.2 | 76.0 | 74.9 | 73.8 | 72.7 | 71.6 | 70.6 | 69.6 | 68.7 | 67.7 |
| 5 | 78.2 | 77.0 | 75.8 | 74.7 | 73.5 | 72.5 | 71.4 | 70.4 | 69.4 | 68.4 | 67.5 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 77.1 | 75.9 | 74.8 | 73.6 | 72.5 | 71.5 | 70.4 | 69.4 | 68.4 | 67.5 | 66.6 |
| 3 | 75.6 | 74.4 | 73.2 | 72.1 | 71.1 | 70.0 | 69.0 | 68.0 | 67.1 | 66.1 | 65.2 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |
| | | | | | | | | | | | |
| $a_t$ (g) / tiers | 0.74 | 0.75 | 0.76 | 0.77 | 0.78 | 0.79 | 0.80 | 0.81 | 0.82 | 0.83 | 0.84 |
| 12 | 68.5 | 67.6 | 66.7 | 65.8 | 65.0 | 64.1 | 63.3 | 62.6 | 61.8 | 61.1 | 60.3 |
| 11 | 68.4 | 67.5 | 66.6 | 65.8 | 64.9 | 64.1 | 63.3 | 62.5 | 61.8 | 61.0 | 60.3 |
| 10 | 68.3 | 67.4 | 66.5 | 65.6 | 64.8 | 64.0 | 63.2 | 62.4 | 61.6 | 60.9 | 60.1 |
| 9 | 67.9 | 67.0 | 66.1 | 65.2 | 64.4 | 63.6 | 62.8 | 62.0 | 61.2 | 60.5 | 59.8 |
| 8 | 67.6 | 66.7 | 65.8 | 64.9 | 64.1 | 63.3 | 62.5 | 61.7 | 61.0 | 60.2 | 59.5 |
| 7 | 67.5 | 66.6 | 65.7 | 64.8 | 64.0 | 63.2 | 62.4 | 61.6 | 60.9 | 60.1 | 59.4 |
| 6 | 66.8 | 65.9 | 65.0 | 64.2 | 63.4 | 62.6 | 61.8 | 61.0 | 60.3 | 59.6 | 58.8 |
| 5 | 66.6 | 65.7 | 64.8 | 64.0 | 63.2 | 62.4 | 61.6 | 60.8 | 60.1 | 59.4 | 58.7 |
| 4 | 65.7 | 64.8 | 63.9 | 63.1 | 62.3 | 61.5 | 60.7 | 60.0 | 59.3 | 58.5 | 57.8 |
| 3 | 64.3 | 63.5 | 62.6 | 61.8 | 61.0 | 60.3 | 59.5 | 58.8 | 58.1 | 57.4 | 56.7 |
| 2 | 61.0 | 61.0 | 60.3 | 59.5 | 58.7 | 58.0 | 57.2 | 56.5 | 55.8 | 55.2 | 54.5 |

Note: In the above table, "tiers" is the number of tiers of 20 ft containers and "$a_t$" the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with no 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier $a_t$ is 0.45g, then the overall weight of the stack is not to exceed 110.9 t, but the weight of container of each tier of stack may be different.

## At least One Tier of 40 ft Containers Stowed above 20 ft Containers (t)

**Table 3.4.3(2)**

| $a_t$ (g) / tiers | 0.30 | 0.31 | 0.32 | 0.33 | 0.34 | 0.35 | 0.36 | 0.37 | 0.38 | 0.39 | 0.40 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 210.8 | 209.9 | 209.2 | 208.4 | 207.6 | 206.8 | 205.9 | 205.3 | 204.5 | 203.6 | 203.5 |
| 11 | 218.4 | 217.6 | 216.8 | 216.1 | 215.3 | 214.6 | 213.9 | 213.0 | 209.8 | 204.5 | 200.4 |
| 10 | 227.4 | 226.7 | 225.9 | 225.3 | 224.7 | 223.5 | 217.4 | 211.5 | 206.0 | 200.8 | 197.0 |
| 9 | 238.6 | 237.9 | 237.2 | 232.1 | 225.3 | 218.9 | 212.8 | 207.1 | 201.7 | 196.5 | 193.1 |
| 8 | 244.0 | 243.1 | 235.5 | 228.4 | 221.7 | 215.3 | 209.3 | 203.7 | 198.3 | 193.2 | 188.4 |
| 7 | 213.5 | 213.5 | 213.5 | 213.5 | 213.5 | 209.1 | 203.3 | 197.8 | 192.6 | 187.7 | 183.0 |
| 6 | 183.0 | 183.0 | 183.0 | 183.0 | 183.0 | 183.0 | 183.0 | 183.0 | 183.0 | 181.4 | 176.8 |
| 5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 | 152.5 |
| 4 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 |
| 3 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |
| | | | | | | | | | | | |
| $a_t$ (g) / tiers | 0.41 | 0.42 | 0.43 | 0.44 | 0.45 | 0.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 |
| 12 | 198.5 | 193.8 | 189.3 | 185.0 | 180.9 | 177.0 | 173.2 | 169.6 | 166.1 | 162.8 | 159.6 |
| 11 | 195.5 | 190.8 | 186.4 | 182.1 | 178.1 | 174.2 | 170.5 | 167.0 | 163.6 | 160.3 | 157.1 |
| 10 | 192.2 | 187.6 | 183.2 | 179.1 | 175.1 | 171.3 | 167.6 | 164.1 | 160.8 | 157.6 | 154.5 |
| 9 | 188.3 | 183.9 | 179.6 | 175.5 | 171.6 | 167.9 | 164.3 | 160.9 | 157.6 | 154.4 | 151.4 |
| 8 | 183.8 | 179.4 | 175.3 | 171.3 | 167.5 | 163.8 | 160.4 | 157.0 | 153.8 | 150.7 | 147.8 |
| 7 | 178.5 | 174.3 | 170.2 | 166.4 | 162.7 | 159.1 | 155.7 | 152.5 | 149.4 | 146.4 | 143.5 |
| 6 | 172.5 | 168.4 | 164.5 | 160.8 | 157.2 | 153.8 | 150.5 | 147.4 | 144.4 | 141.5 | 138.7 |
| 5 | 152.5 | 152.5 | 152.5 | 152.5 | 150.5 | 147.3 | 144.1 | 141.1 | 138.2 | 135.5 | 132.8 |
| 4 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 |
| 3 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |
| | | | | | | | | | | | |
| $a_t$ (g) / tiers | 0.52 | 0.53 | 0.54 | 0.55 | 0.56 | 0.57 | 0.58 | 0.59 | 0.60 | 0.61 | 0.62 |
| 12 | 156.5 | 153.6 | 150.7 | 148.0 | 145.4 | 142.8 | 140.3 | 138.0 | 135.7 | 133.4 | 131.3 |
| 11 | 154.1 | 151.2 | 148.4 | 145.7 | 143.1 | 140.6 | 138.2 | 135.8 | 133.6 | 131.4 | 129.3 |
| 10 | 151.5 | 148.6 | 145.9 | 143.2 | 140.7 | 138.2 | 135.8 | 133.5 | 131.3 | 129.2 | 127.1 |
| 9 | 148.5 | 145.7 | 143.0 | 140.4 | 137.9 | 135.5 | 133.1 | 130.9 | 128.7 | 126.6 | 124.6 |
| 8 | 144.9 | 142.2 | 139.6 | 137.0 | 134.6 | 132.2 | 129.9 | 127.7 | 125.6 | 123.5 | 121.6 |
| 7 | 140.8 | 138.1 | 135.6 | 133.1 | 130.7 | 128.4 | 126.2 | 124.1 | 122.0 | 120.0 | 118.1 |
| 6 | 136.0 | 133.5 | 131.0 | 128.6 | 126.3 | 124.1 | 122.0 | 119.9 | 117.9 | 116.0 | 114.1 |
| 5 | 130.3 | 127.8 | 125.4 | 123.2 | 121.0 | 118.8 | 116.8 | 114.8 | 112.9 | 111.0 | 109.3 |
| 4 | 122.0 | 121.1 | 118.9 | 116.7 | 114.6 | 112.6 | 110.7 | 108.8 | 107.0 | 105.2 | 103.5 |
| 3 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |
| | | | | | | | | | | | |
| $a_t$ (g) / tiers | 0.63 | 0.64 | 0.65 | 0.66 | 0.67 | 0.68 | 0.69 | 0.70 | 0.71 | 0.72 | 0.73 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 129.2 | 127.2 | 125.2 | 123.3 | 121.5 | 119.7 | 118.0 | 116.3 | 114.6 | 113.1 | 111.5 |
| 11 | 127.2 | 125.2 | 123.3 | 121.4 | 119.6 | 117.9 | 116.1 | 114.5 | 112.9 | 111.3 | 109.8 |
| 10 | 125.1 | 123.1 | 121.2 | 119.4 | 117.6 | 115.9 | 114.2 | 112.5 | 111.0 | 109.4 | 107.9 |
| 9 | 122.6 | 120.7 | 118.8 | 117.0 | 115.3 | 113.6 | 111.9 | 110.3 | 108.8 | 107.3 | 105.8 |
| 8 | 119.6 | 117.8 | 115.9 | 114.2 | 112.5 | 110.8 | 109.2 | 107.7 | 106.1 | 104.7 | 103.2 |
| 7 | 116.2 | 114.4 | 112.6 | 110.9 | 109.3 | 107.6 | 106.1 | 104.6 | 103.1 | 101.7 | 100.3 |
| 6 | 112.3 | 110.5 | 108.8 | 107.2 | 105.6 | 104.0 | 102.5 | 101.1 | 99.6 | 98.2 | 96.9 |
| 5 | 107.5 | 105.8 | 104.2 | 102.6 | 101.1 | 99.6 | 98.2 | 96.8 | 95.4 | 94.1 | 92.8 |
| 4 | 101.9 | 100.3 | 98.8 | 97.3 | 95.8 | 94.4 | 93.0 | 91.7 | 90.4 | 89.2 | 87.9 |
| 3 | 91.5 | 91.5 | 91.5 | 90.4 | 89.0 | 87.7 | 86.4 | 85.2 | 84.0 | 82.8 | 81.7 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |
| | | | | | | | | | | | |
| $a_t$ (g) / tiers | 0.74 | 0.75 | 0.76 | 0.77 | 0.78 | 0.79 | 0.80 | 0.81 | 0.82 | 0.83 | 0.84 |
| 12 | 110.0 | 108.5 | 107.1 | 105.7 | 104.4 | 103.0 | 101.8 | 100.5 | 99.3 | 98.1 | 96.9 |
| 11 | 108.3 | 106.9 | 105.4 | 104.1 | 102.7 | 101.4 | 100.2 | 98.9 | 97.7 | 96.6 | 95.4 |
| 10 | 106.5 | 105.0 | 103.7 | 102.3 | 101.0 | 99.7 | 98.5 | 97.3 | 96.1 | 94.9 | 93.8 |
| 9 | 104.4 | 103.0 | 101.6 | 100.3 | 99.0 | 97.8 | 96.5 | 95.3 | 94.2 | 93.0 | 91.9 |
| 8 | 101.8 | 100.5 | 99.2 | 97.9 | 96.6 | 95.4 | 94.2 | 93.0 | 91.9 | 90.8 | 89.7 |
| 7 | 98.9 | 97.6 | 96.3 | 95.1 | 93.8 | 92.7 | 91.5 | 90.4 | 89.3 | 88.2 | 87.1 |
| 6 | 95.6 | 94.3 | 93.1 | 91.9 | 90.7 | 89.5 | 88.4 | 87.3 | 86.3 | 85.2 | 84.2 |
| 5 | 91.5 | 90.3 | 89.1 | 88.0 | 86.8 | 85.7 | 84.7 | 83.6 | 82.6 | 81.6 | 80.6 |
| 4 | 86.7 | 85.6 | 84.5 | 83.4 | 82.3 | 81.3 | 80.2 | 79.3 | 78.3 | 77.3 | 76.4 |
| 3 | 80.6 | 79.5 | 78.5 | 77.5 | 76.5 | 75.5 | 74.5 | 73.6 | 72.7 | 71.9 | 71.0 |
| 2 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 |

Note: In the above table, "tiers" is the number of tiers of 20 ft containers, excluding the number of 40 ft containers stacked on the top, and "$a_t$" the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with at least a tier of 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier $a_t$ is 0.45g, then the overall weight of the stack is not to exceed 162.7 t, excluding the number of 40 ft containers stacked on the top, but the weight of container of each tier of stack may be different.

## 4 Determination of Forces Acting on Containers and Strength of Securing Arrangements

### 4.1 General requirements

4.1.1 The forces acting on the containers are to be determined according to loading conditions and associated motions of the ship. The following forces are to be taken into account: inertial forces of the containers generated by accelerations due to roll, pitch and heave motions of the ship, static gravity forces, wind forces, forces imposed by the securing arrangements and wave impact forces.

4.1.2 The resultant force acting on the containers can be divided into three components as $F_x$, $F_y$ and $F_z$, as shown in Figure 4.1.2, where *ox* is the central axis of roll and $F_x$, $F_y$ and $F_z$ act on the centre of the container, which means that the centre of gravity of the container is assumed to be at the centre of the container. In securing calculation, it may be accepted that the centre of gravity of the container is at 45% of container height.

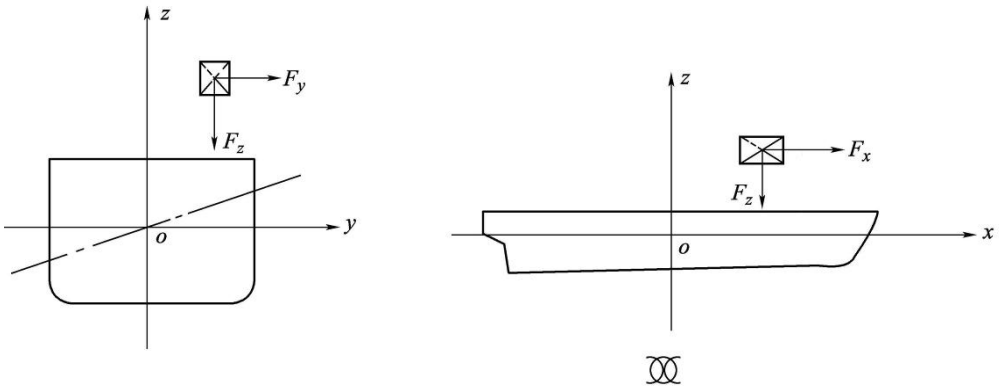



**Figure 4.1.2 Forces Acting on Containers**

### 4.2 Container securing acceleration

4.2.1 The transverse acceleration $a_t$ for container securing calculation is calculated as follows:

$$a_t = (g + b_v) \cdot \sin\phi_m + b_h \cdot \cos\phi_m + (\frac{2\pi}{T_R})^2 \cdot \phi_m \cdot (z - z_{ROLL}) \quad \text{m/s}^2$$

where: $g$—gravity acceleration, to be taken as 9.81 m/s$^2$;
$b_v$—acceleration of vertical motion due to pitch and heaving, in m/s$^2$;
$b_h$—acceleration of transverse motion due to yawing and swaying, in m/s$^2$;
$\varphi_m$ —rolling angle of ship, in rad;
$T_R$—rolling period of ship, in s;
$z$—height from container gravity center position to baseline, in m;
$z_{ROLL}$—height from ship rolling centerline to baseline, in m.

In above calculation formula of transverse acceleration, $b_v$ and $b_h$ are determined by main dimension, block coefficient and speed of ship, and rolling angle and rolling period are determined by main dimension and metacentric height of ship. Transverse acceleration $a_t$ may be determined through CCS ship calculation system.

4.2.2 The vertical acceleration $a_v$ for container securing calculation is calculated as follows:

$$a_v = 0.866 k_x \cdot g \qquad \text{m/s}^2$$

where: $g$—gravity acceleration, to be taken as 9.81 m/s$^2$;
$k_x$—longitudinal distribution coefficient which can be determined through ship calculation systems.

4.2.3 The longitudinal acceleration $a_l$ for container securing calculation is calculated as follows:

$$a_l = g \cdot (0.4 - 0.001 L_{BP}), \text{ but need not be less than 1.5 m/s}^2$$

where: $g$—gravity acceleration, to be taken as 9.81 m/s$^2$;
$L_{BP}$—length between perpendiculars, in m.

### 4.3 Forces acting on containers

4.3.1 The transverse force component $F_y$ parallel to deck is to be calculated as follows:

$$F_y = G a_t + Q \qquad \text{kN}$$

where: $G$—gross weight of the container, in t;
$a_t$—transverse acceleration, in m/s$^2$, see 4.2.1 of this Appendix;
$Q = qA$, in kN, where $q$ is the wind pressure, to be taken as 0.95 kPa for outermost containers at side (for containers at bottom, a splash force of 0.95 kPa is also to be taken into consideration), and as zero for others; $A$ is the projected side area of containers bearing the wind pressure, in m$^2$. If the distance between adjacent container stacks is not more than 1 m, the wind load at containers inside can be omitted. If the distance between adjacent container stacks is 5 m or over, the wind load at containers inside is to be included in its entirety. If the distance is between 1 m and 5 m, linear interpolation is needed. If the exposed area is less than 1/3 of the side area, the wind load can be omitted.

4.3.2 The vertical force component $F_z$ normal to deck is to be calculated as follows:
When checking the strength of the vertical supporting structure of containers:

$$F_z = G a_v \qquad \text{kN}$$

where: $G$ — see 4.3.1 of this Appendix;
$a_v$ — see 4.2.2 of this Appendix.

4.3.3 The longitudinal force component $F_x$ parallel to deck is to be calculated as follows:

$$F_x = G a_l \qquad \text{kN}$$

where: $G$ — see 4.3.1 of this Appendix;
$a_l$ — see 4.2.3 of this Appendix.

### 4.4 Distribution and combination of forces acting on containers

4.4.1 The forces acting on each container are distributed as follows.

(1) The transverse component $F_y$ of force is transmitted to the supporting point $x$ from fore and after end walls of the container. The transverse force $H_i$ transmitted from each end wall of the no. $i$ container is to be obtained from the following formula:

$$H_i = F_{yi}/2 \qquad \text{kN}$$

The distribution of force $H_i$: if the center of gravity of the container is assumed to be the center of the container, $H_i$ /2 acting on top of end wall and $H_i$ /2 on bottom of end wall of the container; if the center of gravity of the container is assumed to be 45% height of the container, 0.45 $H_i$ acting on top of end wall and 0.55 $H_i$ on bottom of end wall of the container.

where: $F_{yi}$ — transverse component of force, see 4.3.1 of this Appendix.

(2) The vertical component $F_z$ of force is transmitted to the supporting structure from the four lower corners of the container. The vertical force *Vi* at each lower corner of the no. *i* container is to be obtained from the following formula:

$$V_i = F_{zi}/4 \qquad \text{kN}$$

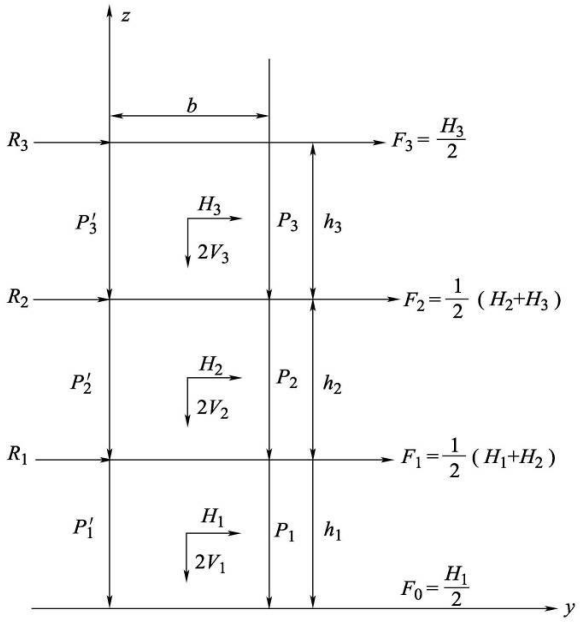
where: $F_{zi}$ — vertical component of force of the no. *i* container, see 4.3.2 of this Appendix.

(3) The longitudinal component of force is transmitted to the supporting point *x* from both side walls of the container. The longitudinal component force $L_i$ transmitted from each side wall of the no. *i* container is to be obtained from the following formula:

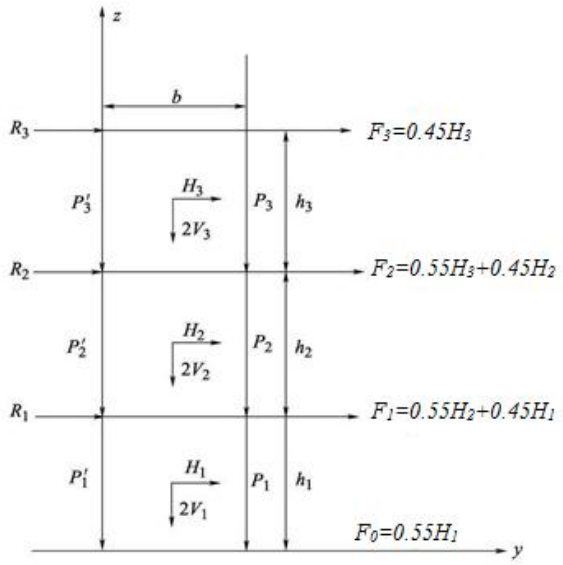
$$L_i = F_{xi}/2 \qquad \text{kN}$$

where: $F_{xi}$ — longitudinal component of force of the no. *i* container, see 4.3.3 of this Appendix.

4.4.2 For containers in a three tier stack, the distribution of force at closed ends is given in Figure 4.4.2 and Table 4.4.2. The distribution of force on side walls may be treated in the same way.




(a) Gravity center at container center




(b) Gravity center at 45% height of container

**Figure 4.4.2 Distribution of Force at Closed Ends of Containers**

**Distribution of Force at Closed Ends of Containers of Each Tier**

**Table 4.4.2**

| Force \ Tier | 1st tier | 2nd tier | 3rd tier |
|---|---|---|---|
| Transverse racking force $R_i$ per container end | $F_3 + F_2 + F_1$ | $F_3 + F_2$ | $F_3$ |
| Maximum vertical pressure $P_i$ per bottom corner | $V_3 + \frac{F_3}{b}(h_3 + h_2 + h_1) + V_2 + \frac{F_2}{b}(h_2 + h_1) + V_1 + \frac{F_1}{b} h_1$ | $V_3 + \frac{F_3}{b}(h_3 + h_2) + V_2 + \frac{F_2}{b} h_2$ | $V_3 + \frac{F_3}{b} h_3$ |
| Minimum vertical pressure $P_i'$ per bottom corner | $V_3 - \frac{F_3}{b}(h_3 + h_2 + h_1) + V_2 - \frac{F_2}{b}(h_2 + h_1) + V_1 - \frac{F_1}{b} h_1$ | $V_3 - \frac{F_3}{b}(h_3 + h_2) + V_2 - \frac{F_2}{b} h_2$ | $V_3 - \frac{F_3}{b} h_3$ |
| Shear force $S_i$ per bottom corner | $0.55(H_3 + H_2 + H_1)$ | $0.55(H_3 + H_2)$ | $0.55 H_3$ |

Note: Where $P_i'$ indicates a negative value, it is a lifting force.

## 4.5 Calculation for lashings

4.5.1 Wire ropes, steel rods or steel chains may be adopted for lashings, the safe working load of which may be determined according to the breaking loads listed in Table 2.2.1 of this Appendix.

4.5.2 Figure 4.5.2 shows a two tier stack of containers, in which internal lashing is arranged to the second tier. If the center of gravity of the container is assumed to be the center of the container, for the selection of the effective sectional area $A$ of the lashing, the residual racking force $T$ ($T$ being as required in 4.7.2 (2) of this Appendix) acting on the containers may be calculated in accordance with the following formula:

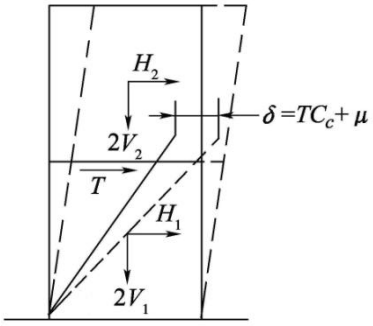



**Figure 4.5.2 Two-Tier Stack**

$$T = \frac{\frac{1}{2} H_1 + H_2 - \frac{AEI_y^2}{l^3}\mu}{\frac{AEI_y^2}{l^3} C_c + 1} \qquad \text{kN}$$

where:

$H_1, H_2$ — see 4.4.1 (1) of this Appendix;

$l$ — overall length of lashing assembly, which is to include torsion element, turnbuckle and eye plate. $l$ can be obtained as follows: $l = \sqrt{l_x^2 + l_y^2 + l_z^2}$, in mm;

$l_x$ — longitudinal length component of lashing assembly, in mm;

$l_y$ — transverse length component of assembly, in mm;

$l_z$ — vertical length component of lashing assembly, in mm;

$E$ — elastic modulus of lashings, to be taken as 10,000 kN/cm$^2$ for steel wire rope, 4,000 kN/cm$^2$ for steel chain based on its nominal diameter, 14,000 kN/cm$^2$ for steel rod (lashed to top of 1st tier containers or bottom of 2nd tier containers), or 17,500 kN/cm$^2$ for steel rod (lashed to top of 2nd tier containers or bottom of 3rd tier containers) or 19,000 kN/cm$^2$ for steel rod (lashed to top of 3rd tier containers or bottom of 4th tier containers);

$A$ — effective sectional area of lashings, in cm$^2$;

$\mu$ — sliding at lower corners of container, in mm, to be taken as 4 mm for 1st and 2nd tier of container door end and 0 for closed end;

$C_c$ — spring constant for container transverse frame, if no actual information available, 0.27 mm/kN for door end, 0.06 mm/kN for closed end and 0.168 mm/kN for side wall.

4.5.3 The lashing forces generated by the lashings are not to exceed the allowable loads as required in 4.7.2 (1) of this Appendix on container corner fittings.

**4.6 Shoring forces**

4.6.1 Where rigid shoring is used for the stowage of containers in holds without cell guide systems, the shoring forces may be determined by the following calculation.

The shoring forces $Q_3$ and $Q_5$ as shown in Figure 4.6.1 are to be calculated as follows:

$$Q_3 = \frac{1}{h_1}[H_4(h_1 - Z_4) + H_5(h_1 - Z_5)] + \frac{1}{h_2}[H_1Z_1 + H_2Z_2 + H_3Z_3] \quad \text{kN}$$

$$Q_5 = \frac{1}{h_1}(H_4Z_4 + H_5Z_5) \quad \text{kN}$$

where: for $H_1$, $H_2$, $H_3$, $H_4$ and $H_5$, see 4.4.1(1) of this Appendix.

$Q_i$ is the shoring force for a stack of containers. Where there are $n$ stacks of containers arranged in the transverse direction and the number $n$ does not exceed 4, the shoring force is to be $nQ_i$; where $n$ exceeds 4, the shoring force $Q_i$ ($n$) may be calculated as follows:

$$\text{If } n-m \le 4, \quad Q_i(n) = Q_i \cdot \left[1 - \frac{(n-4)^2}{2 \cdot n \cdot m}\right]$$

$$\text{If } n-m > 4, \quad Q_i(n) = Q_i \cdot \left(\frac{8+m}{2 \cdot n}\right)$$

where: $n$—number of stacks using the same transverse support;

$m$—maximum tiers of all container stacks.

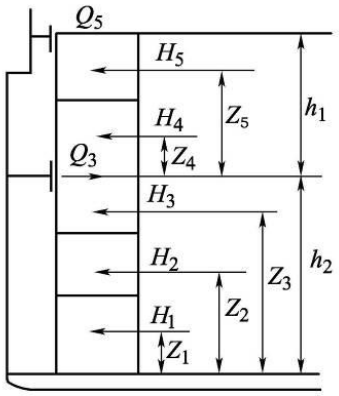



**Figure 4.6.1 Rigid Shoring Forces**

4.6.2 Where elastic shoring is used for the stowage of containers in holds, the shoring forces may be determined by the following calculation:

As shown in Figure 4.6.2, there are three elastic shoring points in one stack of containers, i.e. $i$, $j$ and $k$; and the shoring forces are expressed as $Q_i$, $Q_j$ and $Q_k$ respectively. The shoring forces may be obtained according to the principle that the displacement of the elastic shoring points is equal to the total displacement of containers, with consideration being given to the mutual influence between the shoring forces. The shoring forces $Q_i$, $Q_j$ and $Q_k$ may be obtained as follows:

$$Q_k(C_{sk} + kC_c) + (kQ_i + kQ_j)C_c + \delta_k = C_c[(H_{k+1} + H_{k+2} + H_{k+3} + H_{k+4})k + \sum_{r=1}^{k} H_r(r - \frac{1}{2})]$$

$$Q_j(C_{sj} + jC_c) + jQ_iC_c + \delta_j = C_c[(H_{j+1} + H_{j+2})j + \sum_{r=1}^{j} H_r(r - \frac{1}{2})]$$

$$Q_i(C_{si} + iC_c) + \delta_i = C_c[H_{i+1}i + \sum_{r=1}^{i} H_r(r - \frac{1}{2})]$$

where: $C_{si}$, $C_{sj}$, $C_{sk}$ — spring constants of shoring points $i$, $j$, $k$ respectively, in mm/kN;
$\delta_i$, $\delta_j$, $\delta_k$ — initial gaps at shoring points $i$, $j$, $k$ respectively;
$C_c$ — see Table 4.5.2.

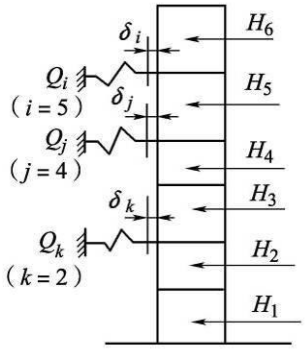



**Figure 4.6.2 Elastic Shoring Forces**

**4.7 Allowable loads on containers**

4.7.1 Forces acting on containers are not to exceed the allowable loads on containers irrespective of the methods of securing arrangements for containers.

4.7.2 As shown in Figure 4.7.2, the allowable loads on freight containers of ISO Standard Series 1 are as follows:

(1) lashing forces acting on the corner fittings:

the horizontal component of force on each end or side wall is not to exceed 150 kN or 225kN, the criteria value depends on the direction of horizontal component, see Figure 4.7.2a) for details;

the vertical component of force on each end or side wall is not exceed 300 kN;

in no case is the resultant of horizontal and vertical components of force to exceed 300 kN.

(2) Racking forces acting on end or side walls:

the transverse racking force on each end or side wall is not to exceed 150 kN;

the vertical racking force on each end or side wall is not to exceed 100 kN.

(3) Vertical tensile and compressive forces acting on the corner fittings:

the vertical tensile force acting at each top corner is not to exceed 250 kN;

the vertical tensile force acting at each bottom corner is not to exceed 250 kN;

the compressive force at each corner post is not to exceed 848 kN.

(4) Transverse compressive and tensile forces acting on the corner fittings:

the transverse compressive (tensile force) at each top corner of 20 ft containers is not to exceed 225 kN;

the transverse compressive (tensile force) at each top corner of 40 ft containers is not to exceed 340 kN;

the transverse compressive (tensile force) at each bottom corner of 20 ft containers is not to exceed 350 kN;

The transverse compressive (tensile force) at each bottom corner of 40 ft containers is not to exceed 500 kN.

Where a buttress supports the stack at an intermediate level, the total transverse compressive (tensile) force acting at the level is not to exceed 575 kN for 20 ft containers and 840 kN for 40 ft containers.

(5) For 45 ft containers, vertical compressive forces acting on the corner fittings:

if the container is stacked at 45 ft position and supported in 45 ft position, the compressive force at bottom corner post is not to exceed 942 kN;

if the container is stacked at 40 ft position and supported in 40 ft position, the compressive force at bottom corner fitting is not to exceed 404 kN.

For 45 ft containers, other allowable loads are the same as those for 40 ft containers.

(6) For containers with special dimensions (e.g. 43 ft, 48 ft and 53 ft), test results need to be submitted.

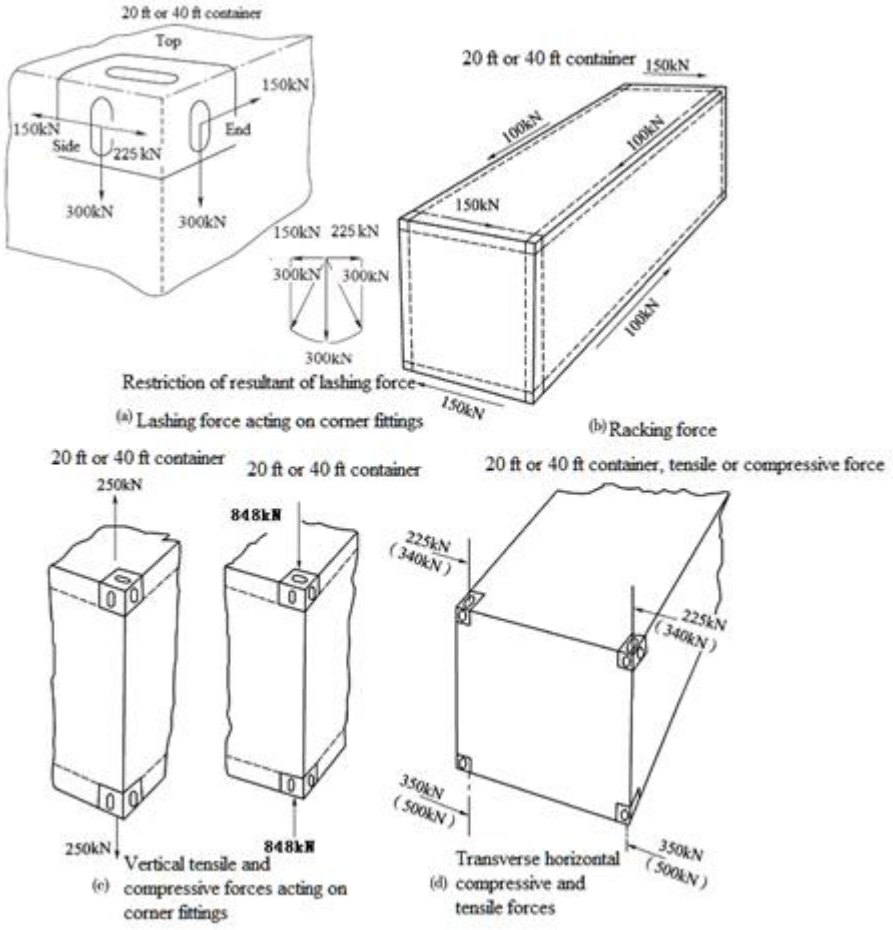



**Figure 4.7.2 Allowable Loads on 20/40 ft Containers**

## 4.8 Direct calculation of container securing

4.8.1 General requirements

4.8.1.1 2-dimensional beam model may be used to model containers and calculate the strength of containers and their lashings.

4.8.1.2 Each stack may be analysed separately unless there are connections between the stacks such as double cones or similar.

4.8.1.3 The flange thickness of twist locks or cones are to be included in clearances between container stacks.

4.8.2 Modelling of geometry

4.8.2.1 Beam elements are used to model container frames according to the dimension of containers.

4.8.2.2 The spring constant of the door end and of closed end are to be obtained respectively by adjusting the cross sectional area of the corner post as indicated by Figure 4.8.2.2:

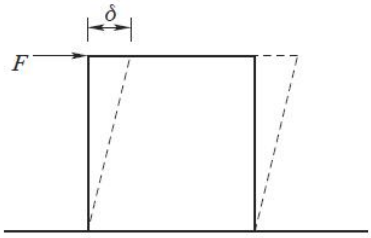



**Figure 4.8.2.2 Spring Constant of Door End and of Closed End**

For example: If the spring constant of the door end of the container is 0.291 mm/kN, when $F$=1,000 kN, the deflection of the frame is 291 mm.

4.8.2.3 Twist locks between two tiers of containers are to be modeled as rigid elements, with a hinge at one end to avoid transfer of bending moments.

4.8.2.4 Cones between two tiers of containers are to be modeled as non-linear elements capable of taking compression but not tension.

4.8.2.5 Lashing rods are to be modeled according to actual elastic modulus and cross sectional area.
4.8.3 Boundary conditions and loading
4.8.3.1 Elements attached to the ship structure are to be restricted from translation.
4.8.3.2 Loads should be applied as point loads in the corners of the containers. The transverse forces are applied to the top and bottom corners while vertical forces are only applied to the bottom corners of the container.
4.8.4 Calculation results
4.8.4.1 Results are to be extracted from the model to check whether the containers comply with the allowable loads of containers specified in 4.7 of this Appendix and whether the loads on the securing devices exceed their SWL.

## 5 Strength Evaluation of Container Securing Structure

### 5.1 General requirements
5.1.1 These requirements apply to the lashing bridge and stanchion structure and supporting structure of fixed securing devices (lashing eye plate, deck ring, etc.) on the deck of container ships.

### 5.2 Lashing bridge
5.2.1 The SWL of lashing rods (50% of the breaking load) is theoretically the maximum load to check the strength of lashing bridges.
5.2.2 To check the strength of a lashing bridge, loads are to be applied according to the condition where the maximum lashing force may occur in the container securing manual, and the lashing force is to be obtained by calculating according to the container securing manual. The lashing force is to be applied in line with the lashing rods and can be decomposed into force components in longitudinal, transverse and vertical direction. The lashing force is applied to the securing eye plate of the lashing bridge. In calculating lashing forces, the relative displacement between the lashing bridge and the container stacks are to be taken into account, which is not to exceed the values given in Table 5.2.2.

**Relative displacement between lashing bridge and container stacks**

**Table 5.2.2**

| Lashing bridge of 1-tier container height | Lashing bridge of 2-tier container height | Lashing bridge of 3-tier container height |
|---|---|---|
| 10 mm | 25 mm | 35 mm |

5.2.3 In the initial design, forces may be applied according to the condition where the maximum lashing force may occur in reality. The lashing force is to be taken as 60% safe working load of each lashing rod (or other securing devices).
5.2.4 When checking the strength of lashing bridges, conditions where lashing forces are applied to forward and aft part lashing bridges together as well as respectively are to be calculated.
5.2.5 To better describe the force distribution of each structural part in each direction, strength checking of lashing bridge is to adopt 3-dimensional finite element structural analysis. The extent of the model, the elements and the boundary conditions are based on the following principles:
(1) The finite element model is to include all lashing bridges above the deck or hatch cover. The boundary conditions are to restrict all translations between elements and deck or hatch cover.
(2) The mesh size of the plate element is generally 100 mm × 100 mm, and triangle elements are to be avoided as far as possible in high stress areas and high stress changing areas.

### 5.3 Deck stanchion
5.3.1 In design of deck stanchion, the most critical conditions are to be taken into account, as well as the transverse load and vertical load acting on the stanchion.
5.3.2 Where lashing points are arranged on the stanchion, the horizontal and vertical components of lashing forces are also to be taken into account.

### 5.4 Fixed securing device
5.4.1 SWL of the connected securing device is to be used as the design load of supporting structure of fixed securing device.

### 5.5 Strength criteria
5.5.1 Allowable stresses for lashing bridge structures, deck stanchion structures and supporting structures

of fixed cargo securing devices under various conditions are as follows:

Allowable shear stress: $[\tau] = 0.4\ R_{eH}$

Allowable equivalent stress: $[\sigma] = 0.88\ R_{eH}$

where $R_{eH}$ is the yield stress of the material, in N/mm$^2$.

# Appendix 2 DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS

## 1 General

### 1.1 Application

1.1.1 This Appendix applies to direct strength calculations of container ships as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

## 2 DIRECT CALCULATIONS OF STRENGTH OF PRIMARY STRUCTURES OF CARGO AREA

### 2.1 General requirements

2.1.1 The direct strength calculations for cargo holds are applicable to the evaluation of the strength of the following primary structures within cargo area in typical loading conditions:

(1) double bottom structure (bottom plating, inner bottom plating, girders, floors);

(2) double side structure (side shell plating, inner hull plating, longitudinal stringers and transverse web frames);

(3) Transverse bulkhead structure (transverse bulkhead plating, bulkhead webs);

(4) Deck structure (deck, torsion box).

2.1.2 Where fuel oil tanks are arranged between cargo holds amidships, strength evaluation is to be carried out for fuel oil tank area in accordance with 2.8 of this Appendix.

### 2.2 Structural modeling

2.2.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for requirements for structural modeling.

2.2.2 Normally, the longitudinal extent is to cover the length of 1/2 hold + 1 hold + 1/2 hold within the cargo area amidships, namely the length of one 40 ft bay + two 40 ft bays + one 40 ft bay. The vertical extent is to be taken up to the hatch coaming. A full-breadth model is to be required for transverse extent.

2.2.3 The model is generally to cover transverse watertight bulkheads and transverse support bulkheads. The transverse support bulkheads are at both ends and the middle of the model, and typical finite element models are shown in Figures 2.2.3(1) to (3).

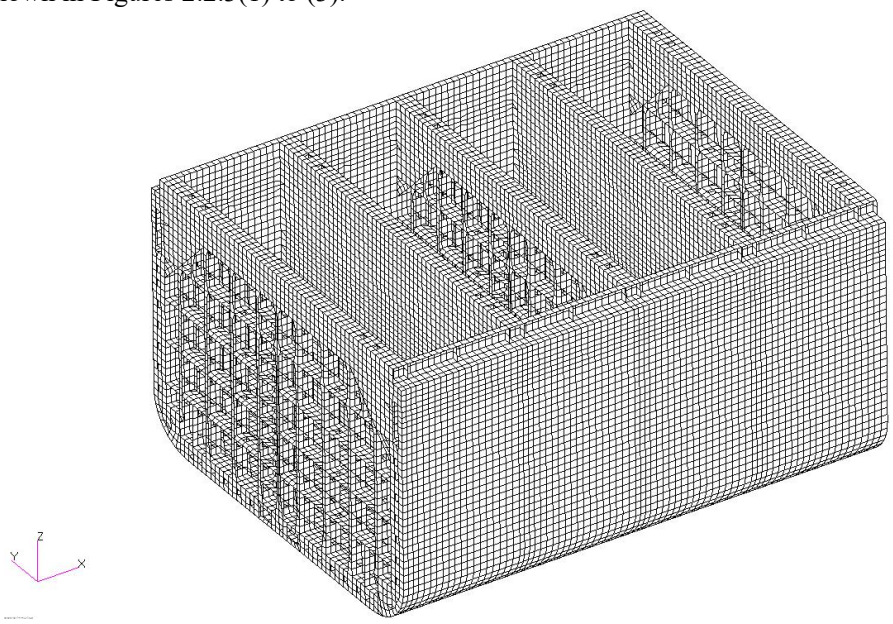



**Figure 2.2.3(1) Typical finite element model**

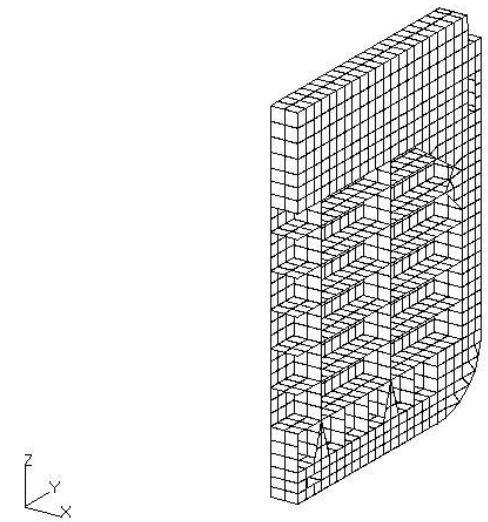



**Figure 2.2.3(2) Typical finite element model of watertight transverse bulkhead (half-breadth)**

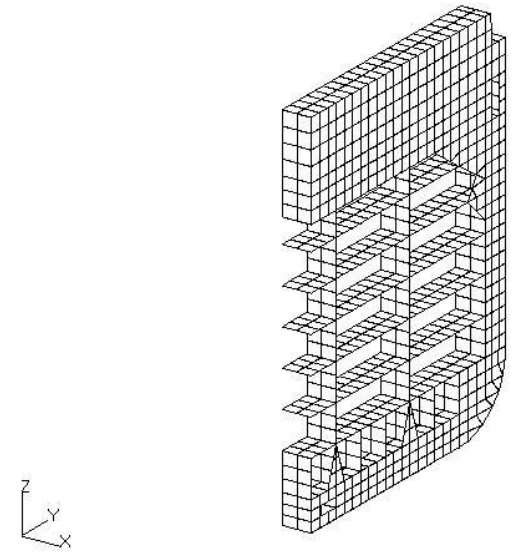



**Figure 2.2.3(3) Typical finite element model of transverse support bulkhead (half-breadth)**

**2.3 Design loads**

2.3.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for design loads.

2.3.2 The global loads include still water bending moment and wave bending moment. The still water bending moment $M_S$ is to be taken as the permissible hogging moment $\overline{M}_{S-Hog}$ and permissible sagging moment $\overline{M}_{S-Sag}$ provided by the designer. Vertical wave bending moment $M_W$ includes hogging wave bending moment $M_{W-Hog}$ and sagging wave bending moment $M_{W-Sag}$, is to be calculated in accordance with 7.2.2.3 of Section 2 of this Chapter.

2.3.3 Local loads include:

(1) hydrostatic pressure;

(2) hydrodynamic wave pressure;

(3) self-weights of hull structure and containers;

(4) dynamic loads of hull structure and container induced by the ship's motions, see 2.3.5 for the acceleration of ship's motions.

2.3.4 External hydrodynamic wave pressure is an additional pressure induced by local wave loads,

consisting of hydrodynamic wave crest pressure and hydrodynamic wave trough pressure. See 1.5.3.3(4) and (5) of Chapter 1 of this PART for hydrodynamic wave crest pressure $p_{hd}$. The hydrodynamic wave trough pressure $p_{hd1}$ is to be calculated as follows, the distribution is shown in Figure 2.3.4.

$$p_{hd1} = \max\left(-p_{hd}, \rho_w g\left(z - d_1\right)\right) \quad \text{KN/m}^2$$

where: $p_{hd}$ — to be taken in accordance with 1.5.3.3(4) of Chapter 1 of this PART;

$\rho_w$ — density of seawater, taken as 1.025 t/m$^3$;

$g$ — acceleration due to gravity, $g$ = 9.81 m/s$^2$;

$z$ — vertical distance from calculation point to baseline, in m;

$d_1$ — draught in the considered load condition, in m.

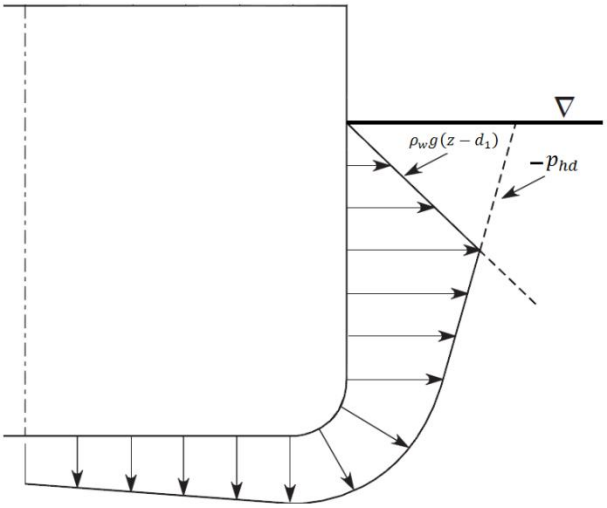



**Figure 2.3.4 Distribution of hydrodynamic wave trough pressure on transverse section of the hull**

2.3.5 The vertical acceleration $a_v$ induced by the ship's motions is to be calculated as follows, positive downwards:

$$a_v = f_{LC}(C_{ZH}a_z - C_{ZP}a_p(x - 0.45L)) \quad \text{m/s}^2$$

where: $f_{LC}$ — coefficient, to be taken as follows:

= -1.0 where the considered load condition is sagging condition;

= 1.0 where the considered load condition is hogging condition;

$C_{ZH}$ — load combination factor of heave acceleration, $C_{ZH}$ =0.15-0.5 $f_T$, $f_T = d_1/d$;

$a_z$ — to be calculated in accordance with 1.5.2.1(3) of Chapter 1 of this PART;

$C_{ZP}$ — load combination factor of pitch acceleration, taken as 0.7;

$a_p$ — to be calculated in accordance with 1.5.2.1(5) of Chapter 1 of this PART;

$x$ — $X$ coordinate of the calculation point, in m;

$L$ — length of the ship, in m.

The longitudinal acceleration $a_l$ induced by the ship's motions is to be calculated in accordance with 1.5.2.2(7) of Section 5, Chapter 1 of this PART and the speed is to be taken as half of the maximum service speed.

## 2.4 Loading conditions

2.4.1 The applicable loading conditions are to be checked according to Table 2.4.1. For more severe loading conditions in the loading manual not covered by the Table, direct strength calculation is to be carried out. Figure 2.4.1 shows various loading conditions.

**Loading Conditions** **Table 2.4.1**

| Loading condition | Condition description | Still water bending moment | Wave bending moment | Draught | hydrodynamic wave pressure | Container weight | dynamic acceleration of hull structure and containers |
|---|---|---|---|---|---|---|---|
| 1 | Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers | $\overline{M}_{s-Hog}$ | $M_{w-Hog}$ | $d$ | $p_{hd}$ | 40ft heavy container | $a_v$ |
| 2 | Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers | $\overline{M}_{s-Hog}$ | $M_{w-Hog}$ | $d$ | $p_{hd}$ | 40ft heavy container | $a_v$ |
| 3 | Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers | $\overline{M}_{s-Hog}$ | $M_{w-Hog}$ | $d$ | $p_{hd}$ | 20ft heavy container | $a_v$ |
| 4 | Full within hold of all holds and on all hatch covers | $\overline{M}_{s-Sag}$ | $M_{w-Sag}$ | $0.9d$ | $p_{hd1}$ | 20ft heavy container | $a_v$ |
| 5 | Full within hold of all holds and on all hatch covers | $\overline{M}_{s-Hog}$ | $M_{w-Hog}$ | $d$ | $p_{hd}$ | 40ft light container | $a_v$ |
| 6 | Full within hold of all holds and on all hatch covers | $\overline{M}_{s-Hog}$ | $M_{w-Hog}$ | $d$ | $p_{hd}$ | 40ft heavy container | $a_v$ |
| 7 | Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers (heeling of ship) | — | — | $d$ | — | 40ft heavy container | — |
| 8 | Full within hold of all holds and on all hatch covers (heeling of ship) | — | — | $d$ | — | 20ft heavy container | — |
| 9 | Full within hold of all holds and on all hatch covers (longitudinal motions of ship) | $\overline{M}_{s-Sag}$ | $M_{w-Sag}$ | $d$ | $p_{hd1}$ | 40ft heavy container within holds, 20ft heavy container on hatch covers | $a_l$, $a_v$ |
| 10 | Damage (heeling of ship) | $\overline{M}_{s-Sag}$ | — | $d_{dam}$ | — | 40ft Heavy container (except the damaged tank in the middle) | — |

Notes:

(1) $d$ — draught, in m;

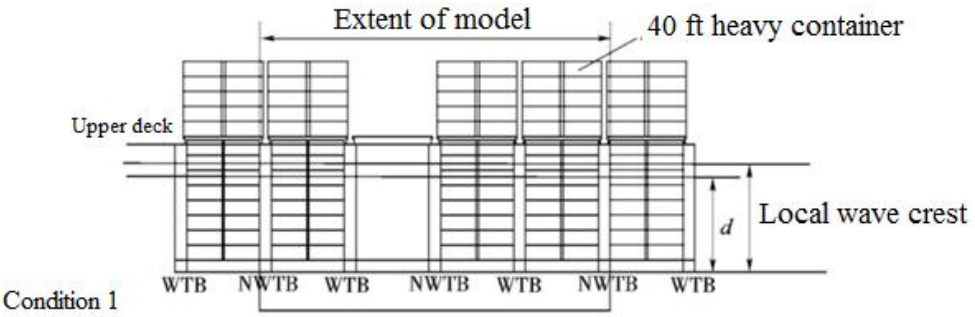
(2) Heavy container — the weight of a container is to be taken as permissible stack weight divided by the maximum number of tiers;

(3) Light container — the weight of a container is not to be greater than the values taken as follows:

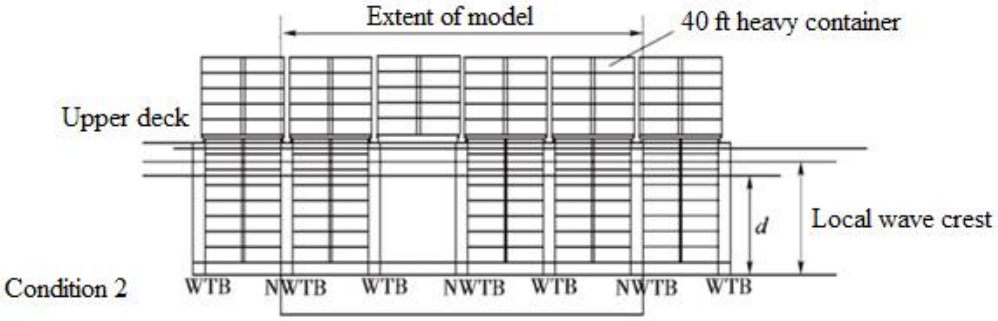
In hold: 55% of the weight of heavy container;

On hatch covers: to be taken as 90% of the permissible stack weight divided by the maximum number of tiers or 17 tons,

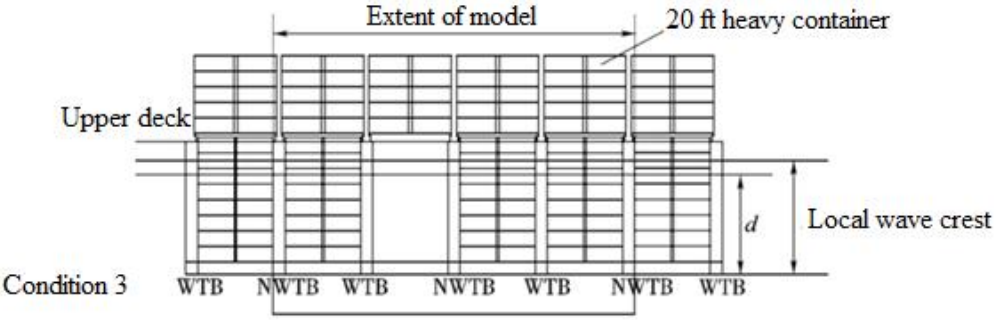
whichever is the lesser;
(4) for condition 7 and 8, the heeling angle is to be calculated in accordance with Section 5, Chapter 1 of this PART; Where the direct calculation of wave load is available, the heeling angle predicted by direct calculation may be accepted, but not to be less than 18°;
(5) for condition 9, loads within hold and on hatch covers to be determined as specified in 2.4.3 and 2.4.4;
(6) where a hold consists of two or more 40 ft bays, then each bay is to be considered as entirely empty;
(7) definition for $d_{dam}$ is defined in 2.4.5 of this appendix.



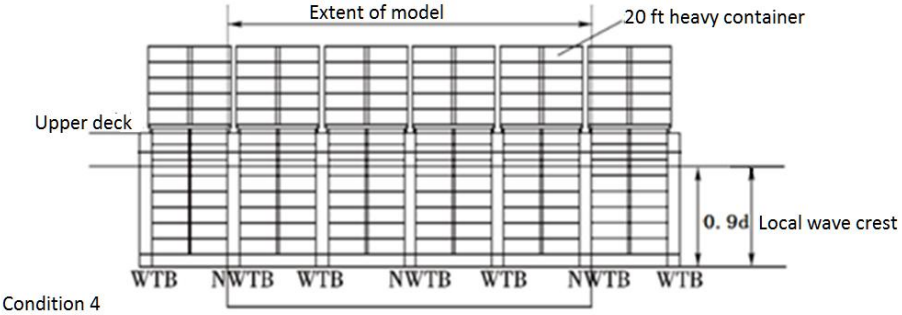
Condition 1



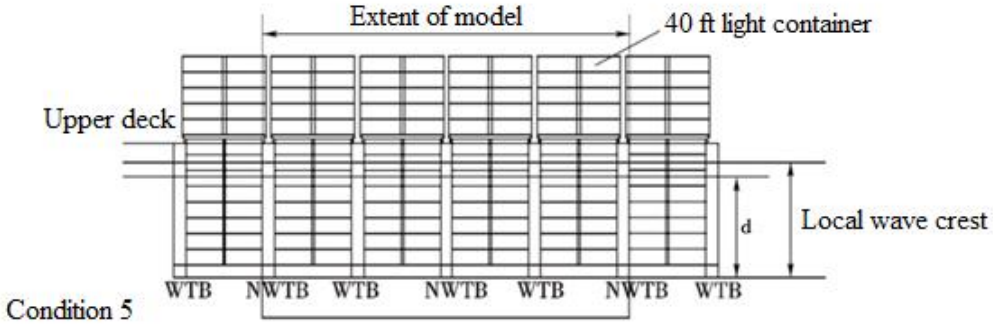
Condition 2



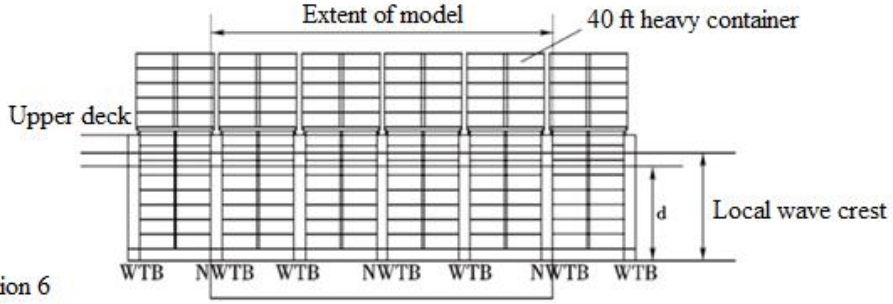
Condition 3



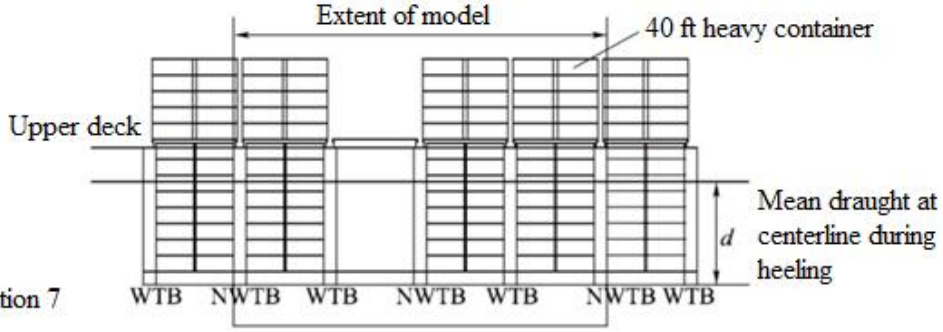
Condition 4



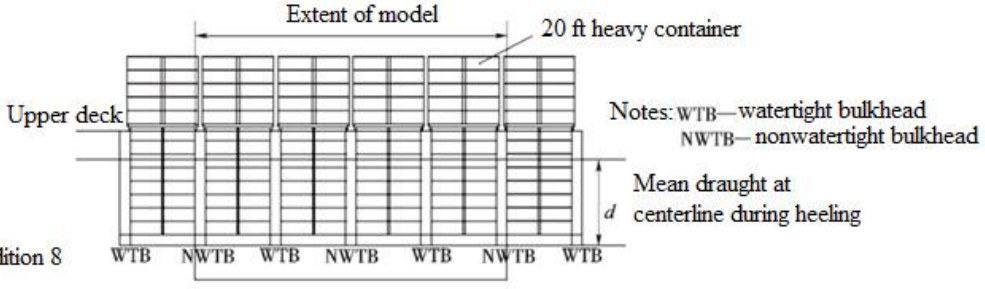

Condition 5




Condition 6




Condition 7




Condition 8

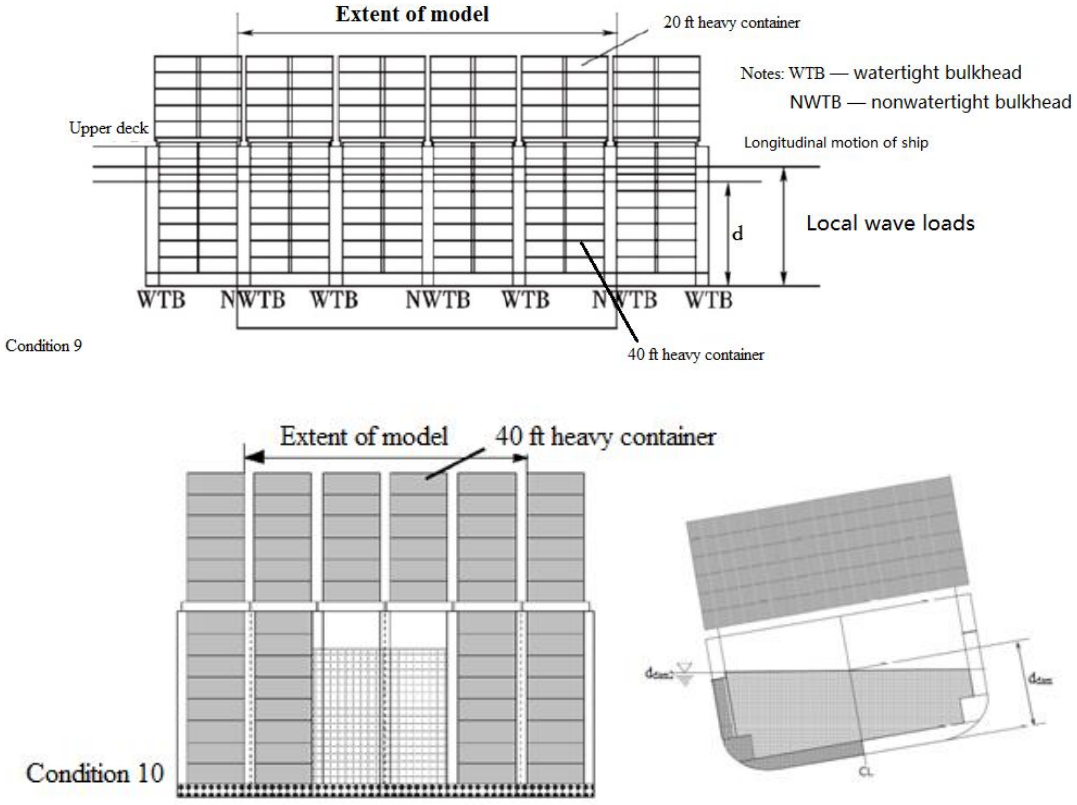



**Figure 2.4.1 Loading conditions**

2.4.2 For heeling conditions (conditions 7 and 8), the load components are to be calculated assuming that the ship heels to maximum heeling angle. The transverse load components of containers in holds are to act as a group of concentrated forces on transverse bulkheads, with the locations of container corners corresponding to transverse bulkheads as acting points. The load components from containers on deck are to act as a group of horizontally distributed shear forces on nodes of top elements of the transverse coaming.

2.4.3 Where deck is fitted with torsion box girders and the span of the cross deck box is not greater than 13.0 m, the condition 9 need not be considered.

2.4.4 For surging condition (condition 9), the forces arising from acceleration of the longitudinal motion of each container within hold is to be distributed from corresponding corners of the container to primary members of the transverse bulkhead (or the transverse support bulkhead) in way of cell guides. Determination of loads due to containers on hatch covers is as follows:

(1) The longitudinal forces from containers on each hatch cover are to be calculated at mid-height of the stack. The moment about the stack base caused by longitudinal forces may be ignored.

(2) The number of tiers of containers is the maximum one of loaded containers, and the maximum stack weight and the number of tiers are to be those permitted in the loading manual or the cargo handling manual.

(3) The longitudinal forces from containers sited between the ship's side and the longitudinal hatch coamings may be ignored.

(4) 15% of the total longitudinal force acting on hatch covers is to be distributed on nodes at top of longitudinal and transverse hatch coamings to simulate the friction force to which the bearing pads at hatch coamings are subjected due to longitudinal motion.

(5) The remaining 85% of the longitudinal forces on hatch covers are to act on nodes corresponding to the longitudinal stopper positions at one end of the hatch cover (top of the transverse hatch coaming). If the stopper positions are unknown, they are assumed to be located at the mid-breadth of the aft end of the hatch cover. Three covers are to be assumed if the number of hatch covers is unknown.

2.4.5 For damage condition (condition 10), it is assumed that any cargo hold of ship is flooded to the deepest equilibrium waterline. Only the damage of middle hold and the ballast tank on the same side is considered in the FE model. The loads are applied to the container in the same way of that specified in 2.4.2. The maximum height of damage point $d_{dam2}$ and $d_{dam}$ in way of longitudinal centerline is to be determined by the deepest equilibrium waterline.

## 2.5 Boundary conditions

2.5.1 Boundary conditions for local loads

2.5.1.1 For symmetric loading cases (conditions 1, 2, 3, 4, 5, 6, 9, 10), see Table 2.5.1.1(1) for boundary conditions; for asymmetric loading cases (conditions 7 and 8), see Table 2.5.1.1(2) for boundary conditions; nodes, intersection lines and end planes in the Table are shown in Figure 2.5.1.1.

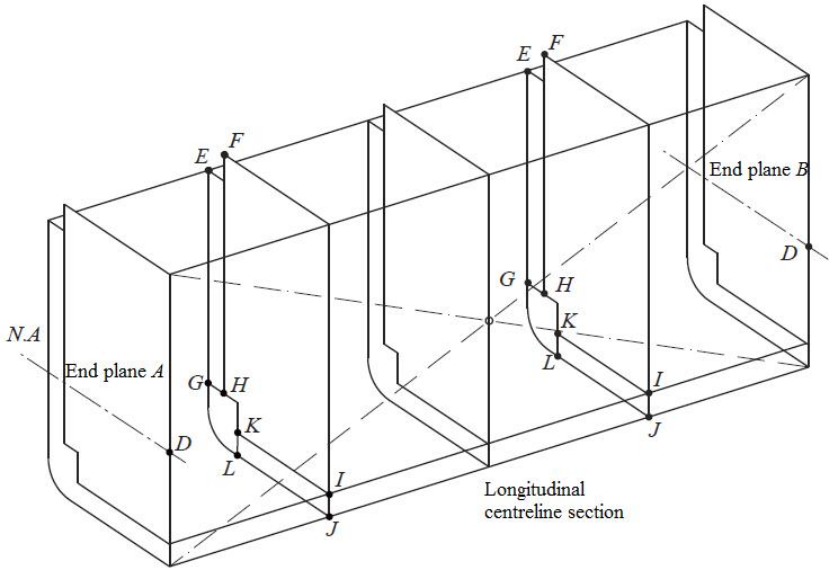



**Figure 2.5.1.1 Boundary Conditions**

2.5.1.2 For symmetric loading cases, vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. For asymmetric loading cases, Horizontal spring elements are to be provided at nodes on intersections of bottom plating and inner bottom plating with forward and aft transverse bulkheads in addition that vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: $G$ — shear modulus of elasticity of material, $G = 0.792\times10^5$ N/mm$^2$ for steel;

$A$ — shearing area of shell plating, inner hull plating, bottom plating and inner bottom plating in way of forward and aft bulkheads, in mm$^2$;

$l_H$ — length of midship hold, in mm;

$n$ — number of nodes on vertical intersections of shell plating and inner hull plating or number of nodes on horizontal intersections of bottom plating and inner bottom plating.

**Boundary Conditions for Symmetric Loading Cases Table 2.5.1.1(1)**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Node *J* | — | Constraint | — | — | — | — |
| End planes *A*, *B* | Constraint | — | — | — | Constraint | Constraint |
| Intersection lines *EG*, *FH* | — | — | Spring | — | — | — |

**Boundary Conditions for Asymmetric Loading Cases Table 2.5.1.1(2)**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| End planes A, B | Constraint | — | — | — | Constraint | Constraint |
| Intersection lines EG, FH | — | — | Spring | — | — | — |
| Intersection lines IK, JL | — | Spring | — | — | — | — |

2.5.2 Boundary conditions for global loads

2.5.2.1 See Table 2.5.2.1 for boundary conditions for global loads. The boundary conditions apply to the calculation of hull girder bending moments for Table 2.4.1 only.

2.5.2.2 An independent point *D* (see Figure 2.5.1.1) is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the overall longitudinal bending moment is to be applied on the point *D*, and the degree of freedom $\delta_x$, $\delta_y$ and $\delta_z$ of each member node for end planes is linked to the independent point.

2.5.2.3 The displacements of the independent point *D* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$ ; the displacement of the independent point *D* within end plane *A* in longitudinal direction is restrained, i.e.: $\delta_x = 0$.

**Boundary conditions for global loads** **Table 2.5.2.1**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Node *J* | — | Constraint | — | — | — | — |
| End planes A, B | Link | Link | Link | — | — | — |
| Independent point D (End plane A) | Constraint | Constraint | Constraint | Constraint | Bending moment | — |
| Independent point D (End plane B) | — | Constraint | Constraint | Constraint | Bending moment | — |

## 2.6 Strength evaluation

2.6.1 Evaluation area

2.6.1.1 Evaluation is to be carried out for middle hold and the primary members with the scope of a transverse framing extending forward and afterward.

2.6.2 Yield strength evaluation

2.6.2.1 The strength check is to be carried out after the stresses due to local load case and global load case are combined. The in-plane stress of the element is to be taken for stress of plate element.

2.6.2.2 In all conditions, permissible stresses of primary members are shown in Table 2.6.2.2.

**Permissible Stresses** **Table 2.6.2.2**

| Structural member | Loading condition | Permissible stress (N/mm$^2$) | |
|---|---|---|---|
| | | $[\sigma_e]$ | $[\tau]$ |
| Deck plating | LC1, 2, 3, 4, 5, 6, 9 | 225/*K* | — |
| Bottom plate, inner bottom plate | LC1, 2, 3, 4, 5, 6, 9 | 225/*K* | — |
| Shell plating, longitudinal bulkhead | LC1, 2, 3, 4, 5, 6, 9 | 225/*K* | 115/*K* |
| Bottom girders | LC1, 2, 3, 4, 5, 6, 9 | 235/*K* | 115/*K* |
| Double bottom floors | LC1, 2, 3, 4, 5, 6, 7, 8, 9 | 175/*K* | 90/*K* |
| Transverse web frames | LC1, 2, 3, 4, 5, 6, 7, 8, 9 | 195/*K* | 95/*K* |
| Longitudinal stringers | LC1, 2, 3, 4, 5, 6, 9 | 225/*K* | — |
| | LC 7, 8 | 175/*K* | 90/*K* |
| Transverse bulkhead plating | LC1, 2, 3, 4, 5, 6, 9 | 180/*K* | 100/*K* |
| | LC10 | 235/*K* | — |
| Transverse bulkhead webs | LC1, 2, 3, 4, 5, 6, 7, 8, 9 | 175/*K* | — |
| | LC10 | 235/*K* | — |
| Connection of the double bottom and side platform to the watertight transverse bulkhead structure | LC10 | 235/*K* | — |
| Cross-deck torsion box | LC 7, 8 | 175/*K* | 90/*K* |

| Structural member | Loading condition | Permissible stress (N/mm$^2$) | |
|---|---|---|---|
| | | $[\sigma_e]$ | $[\tau]$ |
| | LC9 | 175/$K$ | — |
| | LC10 | 235/$K$ | — |
| Bracket toe end with local stress concentration | LC1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 220/$K$ | — |

Notes:
(1) $K$— material factor;
(2) The elements at king-pin area of hatch coaming are directly subjected to the load resulting from hatch cover under loading condition 9, so the permissible equivalent stress is $[\sigma_e]$=195/$K$ N/mm$^2$.

2.6.3 Buckling strength evaluation

2.6.3.1 Finite element buckling strength evaluation is to be carried out for members such as shell plating, inner bottom plating, deck, bulkhead plating of hull structure of containership, web plates and pillars of primary and local supporting members, horizontal/vertical girders of supporting bulkhead.

2.6.3.2 See 2.6.1 for evaluation area.

2.6.3.3 In addition to the requirements of 2.6.3.4 to 2.6.3.8, buckling strength evaluation is to be carried out in accordance with the requirements in 2.6.3.3, Appendix 2, Chapter 7, PART TWO of the Rules for Classification of Sea-going Steel Ships.

2.6.3.4 In buckling strength evaluation, the calculation of the buckling capacity of all panels and stiffeners is to be carried out based on the size after deduction of the standard thickness deduction $t_r$. The standard thickness deduction $t_r$ is shown in Table 2.6.3.4.

**Standard Thickness Deduction** **Table 2.6.3.4**

| Position | Standard thickness deduction (mm) |
|---|---|
| Deck, wing space plating (e.g. second deck, etc.) | 1.0 |
| Longitudinal bulkhead (inner hull plating) | 1.0 |
| Shell plating (including bottom plating), inner bottom | 1.0 |
| Inner structure (girder, floor) of double bottom and wing space | 1.0 |
| Transverse bulkhead structure (watertight, non-watertight) | 0 |
| Cross-deck torsion box | 0 |

Note: If other thickness deduction method is used for buckling strength evaluation (e.g. based on corrosion allowance), the permissible utilization factor is to be considered otherwise.

2.6.3.5 For stresses obtained by calculation of finite element model (including stress components of direct stress and shear stress), if stress component is local stress or including components of local stress, the correction of stress is to be carried out for the stress calculation according to the following formula:

$$\sigma_A = \frac{\sigma t}{t - t_r} \qquad \text{N/mm}^2$$

where: $\sigma_A$ — corrected buckling working stress (including components of axial compressive stress and shear stress), in N/mm$^2$;

$\sigma$ — stress obtained by finite element calculation ((including components of axial compressive stress and shear stress), in N/mm$^2$;

$t$ — plate thickness for finite element calculation, in mm;

$t_r$ —standard thickness deduction, in mm, see Table 2.6.3.4.

2.6.3.6 For permissible buckling utilization factor $\eta_{all}$ used for buckling strength evaluation, see Table 2.6.3.6.

**Permissible buckling utilization factor $\eta_{all}$** **Table 2.6.3.6**

| Structural component | Permissible buckling utilization factor $\eta_{all}$ |
|---|---|
| — Plating(including web plates in way of opening）<br>— stiffener<br>— stiffened panel | 1.00 |
| — strut, pillar | 0.75 |

| Structural component | Permissible buckling utilization factor $\eta_{all}$ |
|---|---|
| — horizontal/vertical girder of supporting bulkhead checked by strut buckling mode | |
| — collision bulkhead (where necessary) | 0.90 |

2.6.3.7 Definition of method for evaluating the stiffened/unstiffened panels of hull panel of containership is shown in Table 2.6.3.7 and Figures 2.6.3.7(1) to 2.6.3.7(6).

**Types of panels and corresponding evaluation methods Table 2.6.3.7**

| Structural element | Evaluation method | Definition for regular panel |
|---|---|---|
| Longitudinal structure , see Figures 2.6.3.7(1), (4), (6) | | |
| external shell plate (bottom plating, side shell plating）<br>inner bottom plating<br>inner hull/longitudinal bulkhead plating<br>horizontal and longitudinal stringer of hopper tank and vertical side plating | SP-A | Length: between web frames<br>Width: between primary supporting members (PSM) |
| Hatch coaming side plating | SP-A or UP-A | Length: between web frames<br>Width: between primary supporting members (PSM) |
| Upper deck | SP-B[5] | Length: between web frames<br>Width: between primary supporting members (PSM) |
| Double bottom longitudinal girders | SP-B[5] | Length: between web frames<br>Width: height of the whole web plate |
| Transverse structure, see Figure 2.6.3.8(2) | | |
| Transverse framing of deck/web plate of cross-deck torsion box, including bracket of regular mesh shape | SP-A[6] | Local stiffener / between face plate/PSM |
| Transverse framing of deck/ web plate of cross-deck torsion box, including bracket of irregular mesh shape | SP-B[5] | Local stiffener /between face plate/PSM |
| Transverse webs of double hull wing tank | SP-B[5] | Length: height of the whole web plate<br>Width: between primary supporting members |
| Transverse webs of double hull wing tank (independent arrangement) | SP-B | Length: height of the whole web plate<br>Width: between primary supporting members |
| Irregular stiffened panel, such as web plate panel in hopper tank and at bilge (continuous alignment arrangement) | UP-A | Local stiffener / between face plate/PSM |
| Irregular stiffened panel, such as web plate panel in hopper tank and at bilge (incontinuous alignment arrangement) | UP-B[5] | Local stiffener / between face plate/PSM |
| Double bottom floors | SP-A[6] | Length: height of the whole web plate<br>Width: between primary supporting members |
| Watertight transverse bulkhead and transverse supporting bulkhead, see Figure 2.6.3.8(3),(4),(5) | | |
| All regular bulkhead stiffened panels, including secondary buckling stiffeners vertical to the regular stiffeners (e.g. carling) | SP-A | Length: between primary supporting members<br>Width: between primary supporting members |
| All irregular bulkhead stiffened panels, such as web plate panels in hopper tank and at bilge | UP-A | Local stiffener / between face plates |
| Bulkhead horizontal web plate, including bracket of regular mesh shape (three arrangement of panel and over) | SP-B[5] | Local stiffener / between face plates |
| Bulkhead horizontal web plate, including bracket of regular mesh shape (two arrangement of panel and less) | SP-B [5] | Local stiffener / between face plates |
| Bulkhead horizontal web plate, including bracket of irregular mesh shape | UP-B | Local stiffener / between face plates |
| Bulkhead vertical web plate, including bracket of regular mesh shape | SP-B [5] | Local stiffener / between face plates |
| Bulkhead vertical web plate, including bracket of irregular mesh shape | UP-B | Local stiffener / between face plates |
| Cross deck, see Figure 2.6.3.8(6) | | |
| Longitudinal deck strips between hatchways | SP-B[5] | Local stiffener / between PSM |

| Structural element | Evaluation method | Definition for regular panel |
|---|---|---|
| Cross deck strips between hatchways | SP-B | Local stiffener / between PSM |

Notes: ① SP means stiffened panel;
② UP means unstiffened panel;
③ A means method A;
④ B means method B;
⑤ For a long side of the web plate panel of primary supporting member, if alongside the face plate, or alongside the attached plate without the property of "in-line support", e.g. property of "pull-in", method B (SP-B or UP-B) is to be selected. For other situations, method A (SP-A or UP-A) is to be selected.
⑥ In typical case that the short edge and sheathing (flange of attached plate) are connected with each other, method A (SP-A or UP-A) is to be selected. However, if a long side of the panel is without the property of "in-line support" and may be pulled in, method B (SP-B or UP-B) is to be selected.
⑦ In-line support means an edge of panel (always) subject to the structural support or restraint of adjacent panel and/or edge stiffener.
⑧ Pull-in means an edge of panel may be pulled freely toward the center of the plate.
In this Table, "in-line support" and "pull-in" represent opposite mechanical properties.

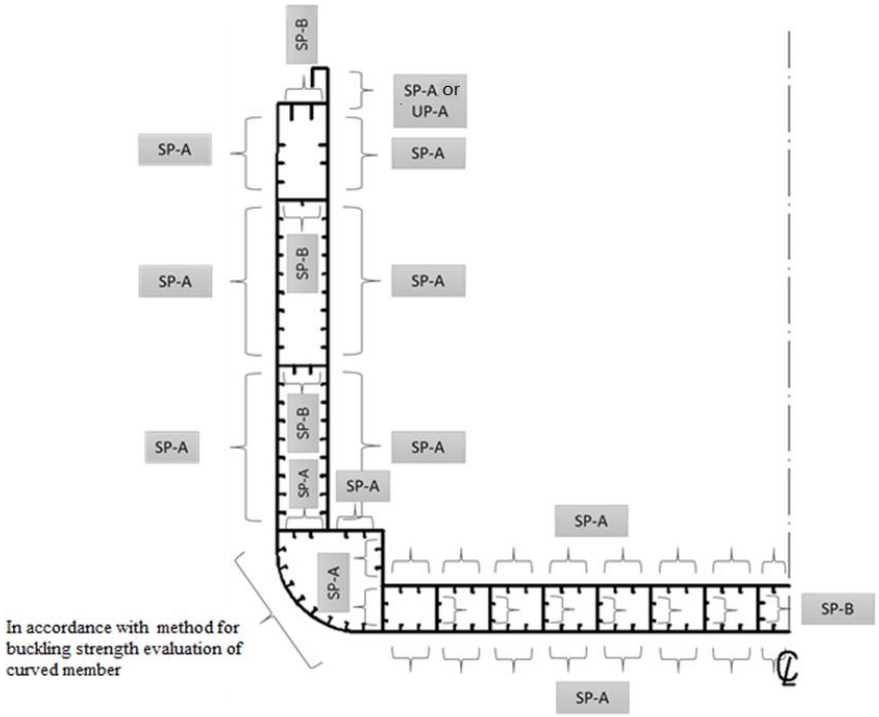



**Figure 2.6.3.7(1) Typical longitudinal panels of containership**

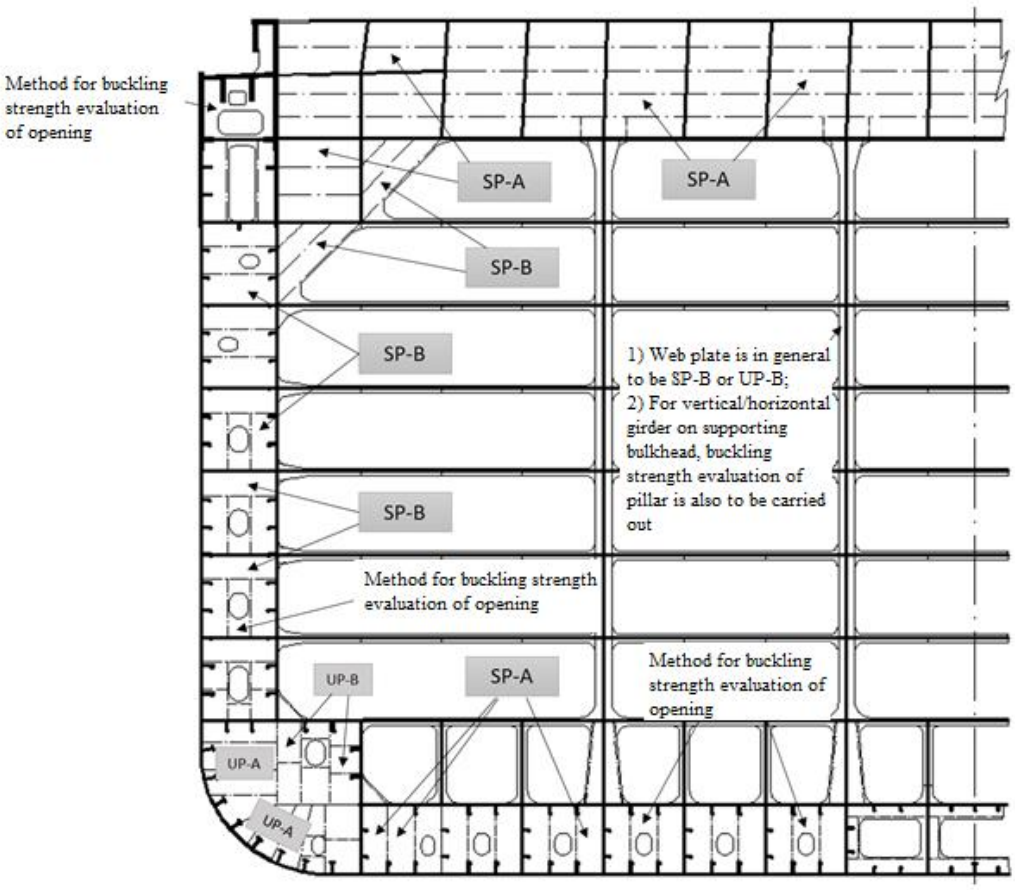



**Figure 2.6.3.7(2) Typical transverse member in way of bulkhead (supporting) of containership**

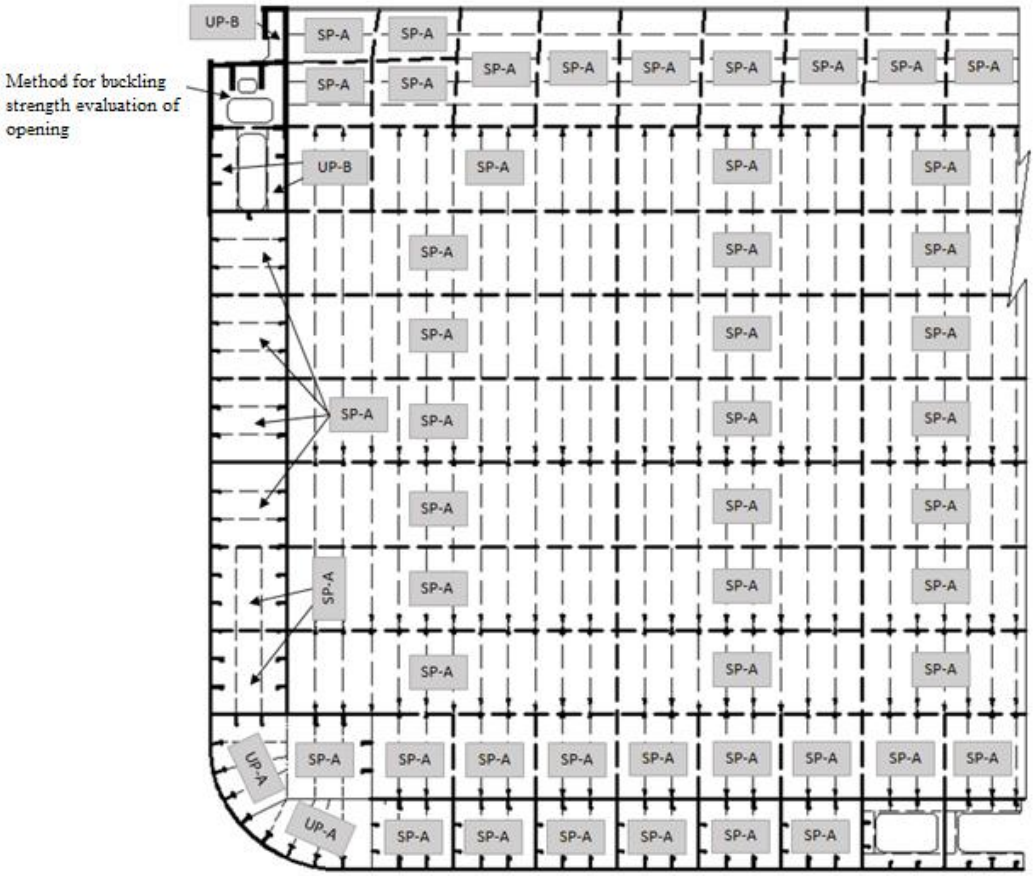



**Figure 2.6.3.7(3) Typical watertight transverse bulkhead of containership**

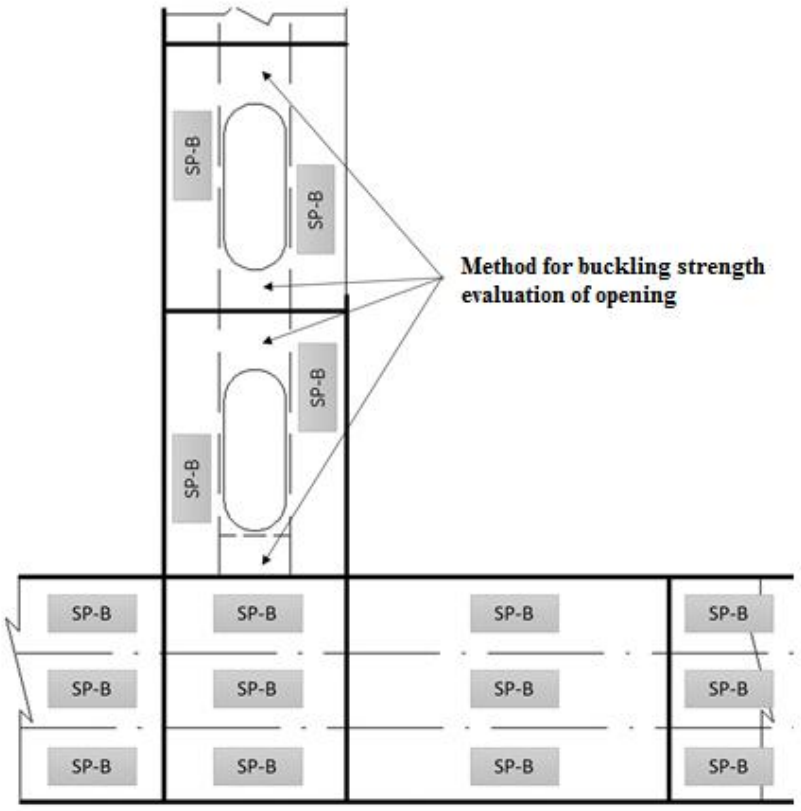



**Figure 2.6.3.7(4) Transverse bulkhead vertical girder and double bottom girders**

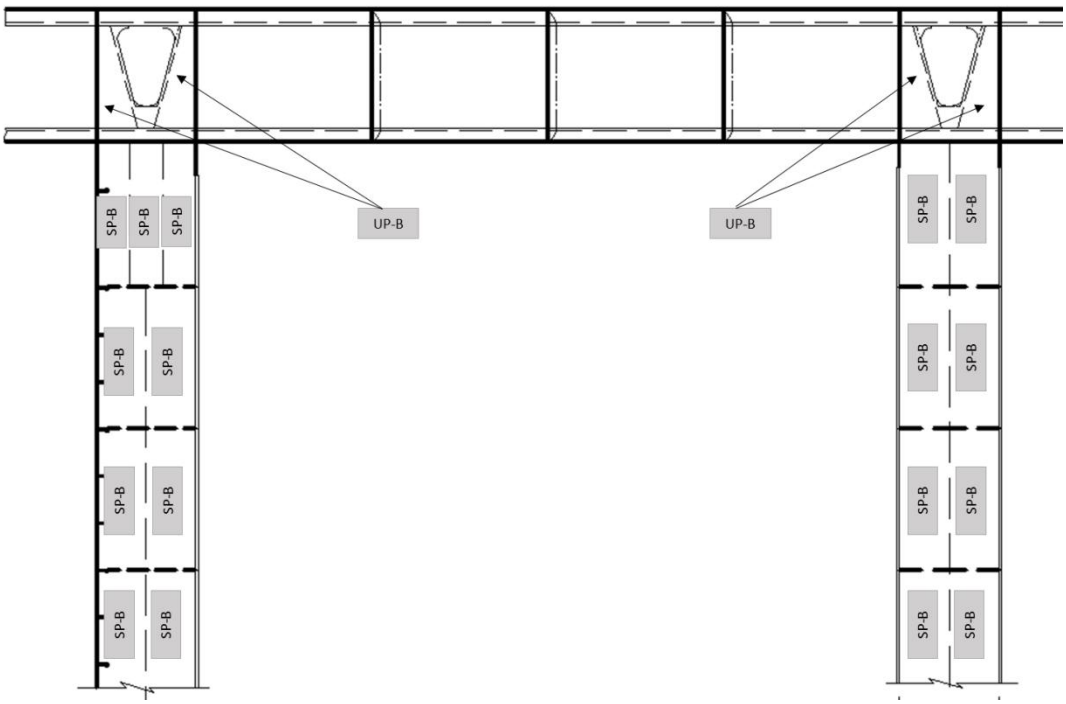



**Figure 2.6.3.7(5) Horizontal girder of transverse bulkhead**

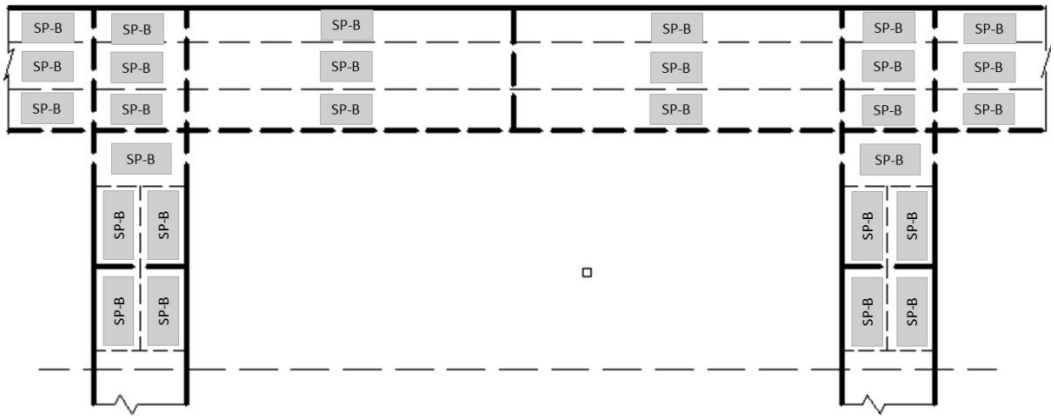



**Figure 2.6.3.7(6) Deck strips between hatchways**

2.6.3.8 For vertical and horizontal webs of supporting bulkhead, see Figure 2.6.3.8, the buckling utilization factor of its members is to be taken as the greater of the maximum buckling utilization factor of web plate panel (stiffened/unstiffened panel) and the maximum buckling utilization factor of pillars of web.

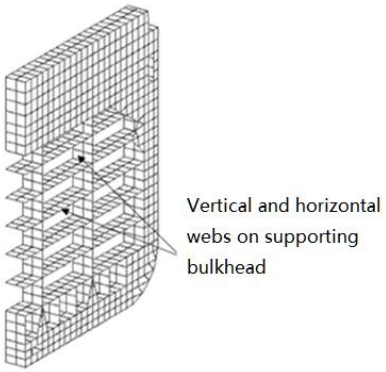



**Figure 2.6.3.8 Vertical and horizontal webs on supporting bulkhead**

## 2.7 Fine mesh analysis

2.7.1 In order to evaluate more accurately the stress level and distribution in way of the concentration of local structural stresses, fine mesh analysis and strength evaluation are at least to be carried out to the following critical parts in the evaluation area required by 2.6.1:

(1) in way of the steps of transverse web frames in the middle of supporting bulkhead and watertight transverse bulkhead (for cargo hold with two supporting transverse bulkheads, the location is the middle of the two supporting transverse bulkheads), see Figure 2.7.1(1).

(2) connection of bottom girder to inner bottom plate and bottom plating in watertight transverse bulkhead area, see Figure 2.7.1(2).

(3) large bracket toe near steps of the supporting bulkhead, see Figure 2.7.1(3).

Fine mesh analysis is also to be carried out if the stress in other critical areas exceeds the permissible criteria.

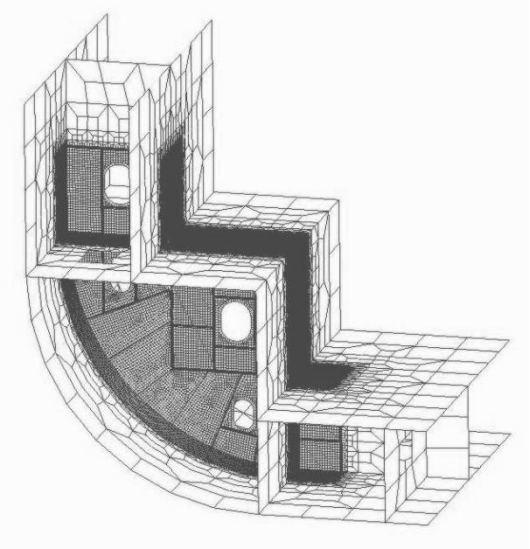


**Figure 2.7.1(1) Refined transverse web frame**

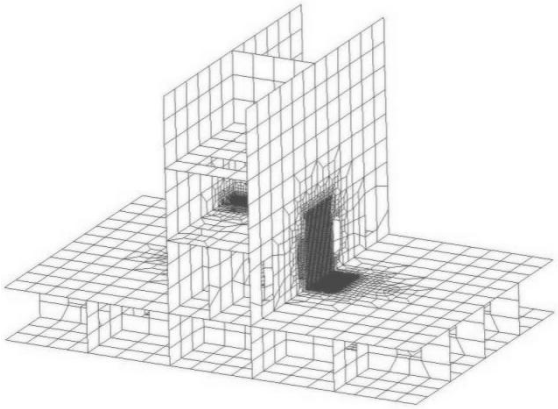


**Figure 2.7.1(2) Refined structural connection of girder to inner bottom plating and bottom plating**

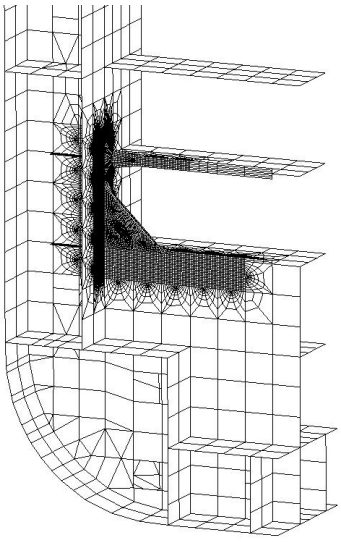


**Figure 2.7.1(3) Refined large bracket toe of supporting bulkhead**

2.7.2 The fine mesh analysis may be conducted by sub-modeling method and embedding method. The individual local finite element model in fine mesh areas is to be used for sub-modeling method, of which the boundary conditions and loads may be obtained from the finite element model of cargo hold blocks. The embedding method is to carry out analysis by embedding the fine mesh model into the finite element model of cargo hold block.

2.7.3 Where the local finite element model is used, its range is to be such that the stress of critical locations is not significantly affected by boundary conditions and applied loads. The boundaries of refined model are to be in consistent with the main support members (e.g. girders and floors) of finite element model o cargo hold blocks.

2.7.4 The mesh size of fine mesh area is not to be greater than 50 mm ×50 mm. In general, the range of fine mesh area is not to be less than 10 elements in all directions of critical positions.

2.7.5 Plate element simulation is to be used for all plating and stiffeners within fine mesh areas. The transition of mesh density is to be maintained stable. The aspect ratio of elements within fine mesh area is to be close to 1 as far as possible so as to avoid the change of mesh density and use of triangular element, as well as the distortion element of which the angle is less than 60° or greater than 120°. In any case, the aspect ratio of element is not to exceed 3. The stiffeners beyond the fine mesh area may be simulated by beam element.

2.7.6 For the transverse web frames, if finite element sub-model method is used, the longitudinal range of model is at least to be of the spacing of "1+1" web frames, i.e., one web frame spacing is extended both before and after the checked transverse web frames, and the web frames at forward and after ends may not be modeled. In addition, the model is to include the full molded breadth and full molded depth of ship.

2.7.7 The fine mesh analysis is to be carried out in accordance with the design conditions specified in this Appendix.

2.7.8 Where sub-model method is used for fine mesh analysis, node displacement obtained from finite element model calculation for cargo hold block is to be applied to the corresponding boundary node of individual local finite element model as a given displacement.

2.7.9 The stress criteria and check method for fine mesh analysis are shown in Table 2.7.9.

**Maximum permissible membrane stress of fine mesh analysis Table 2.7.9**

| Element stress | Yield utilization factor (applicable to all conditions) |
|---|---|
| Element not adjacent to welds | $\lambda_y \leq 1.7$ |
| Element adjacent to welds | $\lambda_y \leq 1.5$ |

where: (1) $\lambda_y$ — yield utilization factor;

$$\lambda_y = \frac{\sigma_e}{[\sigma_e]}$$

(2) In the block finite element model, if the Von Mises stress of element located in the fine mesh check area exceeds the permissible values given in Table 2.7.9, the mean value of Von Mises stress calculation results obtained from fine mesh analysis with the area equivalent to the mesh size of block finite element model is not to exceed the permissible value specified in Table 2.7.9.

(3) The maximum permissible stress is to be based on the mesh size of 50 mm ×50 mm. If smaller size is used, the element mean Von Mises stress on the equivalent areas of above-mentioned mesh size may be compared with the permissible stress. The mean stress is to be calculated only when all the boundaries of element are within the range of above-mentioned mesh size.

Von Mises mean stress is to be weighted based on element area:

$$\sigma_{e-av} = \frac{\sum_1^n A_i \sigma_{e-i}}{\sum_1^n A_i}$$

Where: $\sigma_{e-av}$ — Von Mises mean stress;

$\sigma_{e-i}$ — Von Mises stress of the i$^{th}$ plate element within the area to be considered;

$A_i$ — area of the i$^{th}$ plate element within the area to be considered;

$n$ — number of elements within the area to be considered.

Note 1: The mean stress calculation is to be based on the stress at centroid of the element, and the value is not to be obtained by interpolation and/or extrapolation.

Note 2: Stress averaging method is not allowed to be used for evaluation in way of structural discontinuities and abutting members.

## 2.8 Strength evaluation of fuel oil tank areas

2.8.1 Where fuel oil tanks are provided within the cargo hold areas of container ships, structural strength evaluation is to be carried out for the primary members in the fuel oil tank areas:

(1) boundary structures of fuel oil tanks;

(2) deck and cross deck within fuel oil tank areas;

(3) internal grillage structures of fuel oil tanks, i.e., girders and web frame structures;

(4) double bottom structures below fuel oil tanks (bottom plating, inner bottom plating, girders and floors);

(5) side structures in way of fuel oil tank (side shell plating, inner shell plating, longitudinal stringers, side web frames).

2.8.2 Structural modeling

2.8.2.1 The longitudinal extent of block model is generally to cover the complete structures within the fuel oil tank area, with a cargo hold structure of 40 ft container bay extended both forward and afterward, i.e., “one 40 ft container bay + fuel oil tank + one 40 ft container bay”. The typical finite element model is shown in Figure 2.8.2.1.

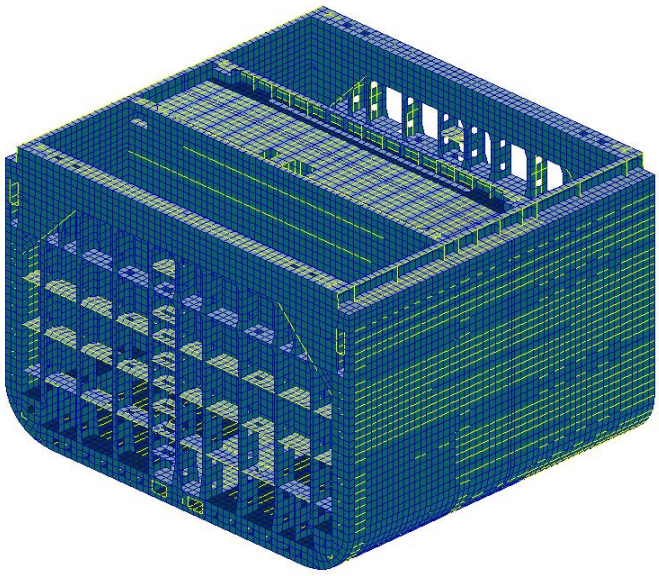


**Figure 2.8.2.1 Finite Element Model of Fuel oil tank**

2.8.2.2 Except the above-mentioned modelling requirements, the other structural modeling requirements are listed in 2.2 of this Appendix.

2.8.3 Design loads

2.8.3.1 Except the liquid pressure of tanks, the other loads are given in 2.3 of this Appendix.

2.8.3.2 Pressures of liquid in tank

The pressures of liquid in tank include the pressure in static load condition and the pressure in dynamic load condition.

(1) The pressure of ballast tanks under dynamic load condition $p_{blast1}$ and the pressure of fuel oil tank under dynamic load condition $p_{HD1}$ are to be calculated by:

$$p_{blast1} = \rho_w (a_v + g) h_1 + 10 p_v \quad \text{kN/m}^2$$

$$p_{HD1} = \rho_f (a_v + g) h_1 + 10 p_v \quad \text{kN/m}^2$$

where:

$h_1$ — distance from the load point to the top of tank, in m;

$\rho_w$ — density of sea water, in 1.025 t/m$^3$;

$\rho_f$ — density of oil fuel, in 1.0 t/m$^3$;

$p_v$ — dynamic load coefficient, to be taken not less than 0, is to be calculated by:

$$p_v = \Delta z - 1.5$$

where: $\Delta z$ — distance between the top of tank and the top of overflow pipe, in m.

(2) The pressure of ballast tanks under static load condition $p_{blast}$ and The pressure of fuel oil tanks under static load condition $p_{HO}$ are to be calculated by:

$$p_{blast} = \rho_w g h_2 \quad \text{kN/m}^2$$

$$p_{HO} = \rho_f g h_2 \quad \text{kN/m}^2$$

Where: $h_2$ — distance from the load point to the top of overflow pipe, in m.

$\rho_w$, $\rho_f$ — the same as 2.8.3.2(1).

2.8.4 Loading conditions

2.8.4.1 In order to fully evaluate the structures of fuel oil tanks, the loading conditions are to be determined according to the arrangement type of fuel oil tanks. The basic principle is that strength analysis

is to be carried out for the structures within fuel oil tank area based on full load of fuel oil tank, alternate load and light ship conditions respectively. Figure 2.8.4.1 gives several typical arrangement types of fuel oil tanks, and the loading conditions of various typical fuel oil tank arrangement types are shown in Table 2.8.4.1(1) to Table 2.8.4.1(3).

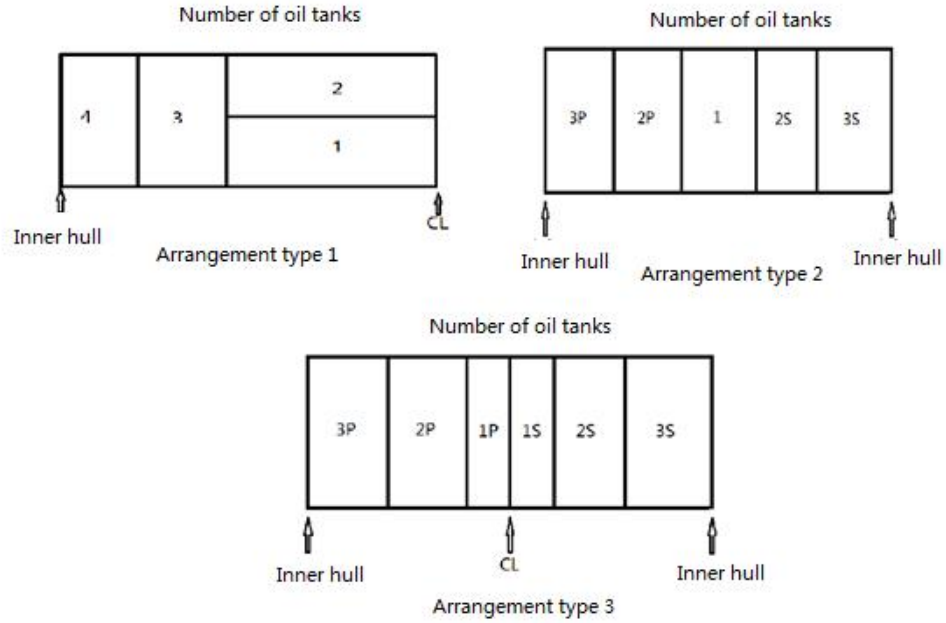



**Figure 2.8.4.1 Diagram of Typical Fuel Oil Tank Arrangement Types (Vertical View)**

Loading condition of Typical Fuel Oil Tank Arrangement Type 1 Table 2.8.4.1(1)

| Loading condition | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wave | Hogging | Hogging | Hogging | Hogging | Sagging | Sagging | Sagging | Sagging | Hogging | Hogging | Hogging | Hogging | Still water | Still water |
| Draught | d | d | d | d | 0.9d | 0.9d | 0.9d | 0.9d | d | d | d | d | d | d |
| Weight of container（TEU） | Light | Light | Light | Light | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy |
| Side ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Bottom ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Oil tank | Empty | Full load | 1，3，4 full load | 2，3，4 full load | 3 full load | 1，2，4 full load | 1，3 full load | 2，4 full load | Empty | Full load | 1，3，4 full load | 2，3，4 full load | 1,3 full load | 2 full load |
| Remark | | | | | | | | | One bay empty | One bay empty | One bay empty | One bay empty | | |

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Loading condition of Typical Fuel Oil Tank Arrangement Type 2 Table 2.8.4.1(2)

| Loading conditions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wave | Hogging | Hogging | Hogging | Hogging | Sagging | Sagging | Sagging | Sagging | Hogging | Hogging | Hogging | Hogging | Still water | Still water |
| Draught | d | d | d | d | 0.9d | 0.9d | 0.9d | 0.9d | d | d | d | d | d | d |
| Weight of container （teu） | Light | Light | Light | Light | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy |
| Side ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Bottom ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Oil tank | Empty | Full load | 1，3 full load | 2 full load | Empty | Full load | 1，3 full load | 2 full load | Empty | Full load | 1，3 full load | 2 full load | 1,3 full load | 2 full load |
| Remark | | | | | | | | | One bay empty | One bay empty | One bay empty | One bay empty | | |

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Loading condition of Typical Fuel Oil Tank Arrangement Type 3 Table 2.8.4.1(3)

| Loading conditions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wave | Hogging | Hogging | Hogging | Hogging | Sagging | Sagging | Sagging | Sagging | Hogging | Hogging | Hogging | Hogging | Hogging | Hogging | Hogging | Hogging | Still water | Still water |
| Draught | d | d | d | d | 0.9d | 0.9d | 0.9d | 0.9d | d | d | d | d | d | d | d | d | d | d |
| Weight of container (TEU) | Light | Light | Light | Light | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy | Heavy |
| Side ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Bottom ballast tank | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | According to loading manual | Empty | Empty |
| Oil tank | Empty | Full load | 3P, 1P, 2S full load | 2P, 1S, 3S full load | Empty | Full load | 3P, 1P, 2S full load | 2P, 1S, 3S full load | Empty | Full load | 3P, 1P, 2S full load | 2P, 1S, 3S full load | Empty | Full load | 3P, 1P, 2S full load | 2P, 1S, 3S full load | Full load | 3P, 1P, 2S full load |
| Remark | | | | | | | | | | | | | One bay empty | One bay empty | One bay empty | One bay empty | | |

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

2.8.5 Boundary conditions

2.8.5.1 The boundary conditions are to be in accordance with the relevant provisions of 2.5 in this Appendix.

2.8.6 Strength evaluation

2.8.6.1 Evaluated areas

2.8.6.1 The mid tank and primary structural members within the extent of one web frame extending forward and afterward are to be evaluated.

2.8.6.2 Yield strength evaluation

(1) The stresses generated by local load case and global load case are to be combined for strength check. The equivalent stress at midpoint of element is to be taken as the plate element stress.

(2) The permissible stress for each primary structural member is given in Table 2.8.6.2.

Permissible stress Table 2.8.6.2

| Structural member | Permissible stress ($N/mm^2$) | |
|---|---|---|
| | $[\sigma_e]$ | $[\tau]$ |
| Bottom plating, inner bottom plating | 225/K | – |
| Side shell plating, inner hull longitudinal bulkhead | 225/K | 115/K |
| Bottom girder | 235/K | 115/K |
| Intersection of oil fuel boundaries and bottom girders | 235/K | 115/K |
| Double bottom floor | 175/*K* | 90/*K* |
| Transverse web frame | 195/*K* | 95/*K* |
| Fuel oil tank bulkhead (excluding inner hull longitudinal bulkhead) | 180/K | 100/K |
| Stringers in fuel oil tank and girder webs between bulkheads | 195/K | 100/K |

Note: *K*— material factor.

2.8.6.3 Buckling strength evaluation

(1) The buckling strength evaluation method is given in the provisions of 2.6 in this Appendix.

2.8.6.4 Fine mesh analysis

(1) If the yield stress exceeds the permissible criteria, fine mesh analysis may be carried out in the critical areas, such as the connection of fuel oil tank boundaries to bottom girders, platform corners within fuel oil tanks, etc. The fine mesh analysis method, element requirements and evaluation criteria are given in 2.7 of this Appendix.

## 3 Direct Calculation of Global Strength of Ship

### 3.1 General requirements

3.1.1 Direct strength calculation of whole ship is to be used to evaluate the global strength of primary hull members under combined bending and torsional moments. In calculation, the following two methods may be used:

Method 1: Analysis where hull girder loads (vertical bending moment, horizontal bending moment and torsional moment) are directly applied to the full ship finite element model.

Method 2: Analysis where direct loads transferred from wave load analysis are applied to the full ship finite element model.

### 3.2 Loading conditions

3.2.1 Still water condition

3.2.1.1 The still water condition is to be selected according to the loading manual, and generally the full load condition where maximum still water bending moment occurs and normal ballast condition where

maximum GM occurs are to be taken.

3.2.1.2 Under the maximum still water bending moment conditions, the ship is to be in or close to upright condition, at or near to the draught $d$, and the still water bending moment within $0.4L$ amidships is the maximum value. If one 40 ft bay in midship range is to be left empty, the maximum still water bending moment condition under this loading condition is required.

3.2.1.3 Consideration is also to be taken if more severe non-homogeneous loading conditions exist in the loading manual.

3.2.2 Wave load condition

3.2.2.1 The still water load condition as determined according to 3.2.1 is taken as the basic loading condition for wave load conditions.

3.2.2.2 Unless specified otherwise in the Appendix, the parameters of wave load conditions, such as length, height and phase of waves, are to be determined by the method and procedure used for equivalent design wave, see Section 5, Chapter 1 of this PART. The wave load conditions are to include head sea,oblique sea and beam sea conditions.

3.2.2.3 The dominant load parameters for direct calculation of wave loads include vertical wave bending moment, horizontal wave bending moment, torsional moment, acceleration and rolling angle. The prediction of the maximum wave load likely to be experienced during the service life covers mainly sea conditions to be encountered during navigation in sea areas around the world, expressed in the probability of waves occurring in various periods and heights. It is suggested that the wave scatter diagram recommended by IACS be adopted. The probability level of dominant load parameters is generally taken as $10^{-8}$, and that of the prediction value of maximum vertical wave bending moment corresponding to the value as required in Section 2 of this Chapter may also be taken.

3.2.3 Loading conditions

3.2.3.1 Each calculation condition is based on different combination of still water condition and wave load condition. Generally, the global strength analysis of container ships is to be checked in accordance with the loading conditions in Table 3.2.3.1. For two-island container ship, the considered condition of the maximum torque at fore and aft ends of the fore island is also to be checked.

**Loading Conditions** **Table 3.2.3.1**

| Loading conditions / Dominant load parameters | homogeneous full load | Normal ballast | Non-homogeneous loading（if any） |
|---|---|---|---|
| Maximum vertical wave bending moment | Applicable | Applicable | Applicable |
| Maximum horizontal wave bending moment | Applicable | Applicable | Applicable |
| Maximum torque in way of $L/2$ | Applicable | Applicable | Applicable |
| Maximum torque in way of $L/4$ | Applicable | Applicable | Applicable |
| Maximum torque in way of $3L/4$ | Applicable | Applicable | Applicable |
| Maximum vertical bow acceleration | Applicable | Applicable | Applicable |
| Maximum rolling angle | - | Applicable | - |

## 3.3 Finite element model for whole ship

3.3.1 Extent of finite element model

3.3.1.1 The ship's global three-dimensional finite element model covers all longitudinal stressed members in main hull within ship's complete length and full breadth, such as deck structure, side and longitudinal bulkhead structure and double bottom structure. The model covers also primary transverse structures such as transverse bulkhead, transverse web frame, transverse deck strip, etc. Local supporting members such as brackets may be omitted in the model. Requirements for openings of web plates of primary structural members are defined in Section 5, Chapter 1 of this PART and openings in brackets may be omitted. A global structural FE model of a typical container ship is shown in Figure 3.3.1.1.

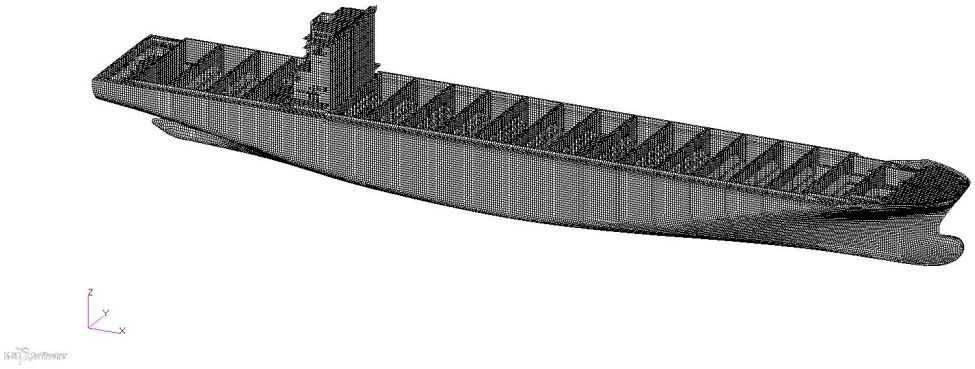


**Figure 3.3.1.1 Global Structural FE Model of a Typical Container Ship**

3.3.2 Selection of elements

3.3.2.1 All kinds of structures in the model are discretized into the following types of elements based on their structural responses:

(1) Shell element (four-node and three-node elements): such as deck, side shell, bottom plating, inner bottom plating, longitudinal and transverse bulkheads, bottom girder, floor, wing space horizontal girder, transverse web frame, etc.

(2) Beam element: such as girder, beam and watertight bulkhead stiffener, etc.

(3) Rod element: such as pillar, etc.

3.3.3 Meshing

3.3.3.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are given in Section 5, Chapter 1 of this PART.

3.3.3.2 The aspect ratio of elements amidships is not to exceed 1:3 and is not to exceed 1:2 elsewhere. Warped quadrilateral elements are to be avoided for meshing.

3.3.4 Boundary conditions

3.3.4.1 In order to prevent rigid displacements, suitable linear displacement constraints are to be applied at corresponding nodes of hull as shown in Figure 3.3.4.1.

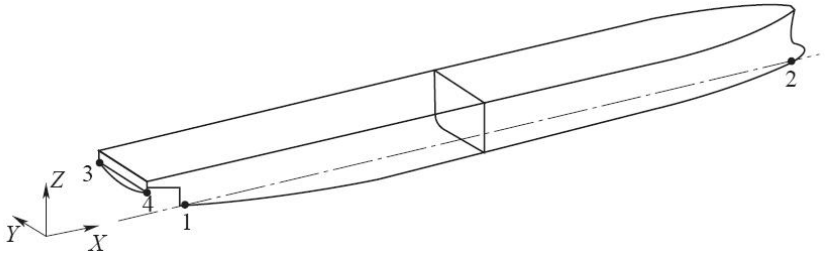



**Figure 3.3.4.1 Diagram of Boundary Conditions**

3.3.4.2 The displacement in transverse direction for bottom plate keel (in longitudinal centerline section) at aft end (node 1 in Figure 3.3.4.1 of this Appendix) is restrained, i.e.: $\delta_y = 0$; the displacements in longitudinal, transverse and vertical directions for bottom plate keel (in longitudinal centreline section) at fore end (node 2 in Figure 3.3.4.1 of this Appendix) are restrained, i.e.: $\delta_x = \delta_y = \delta_z = 0$.

3.3.4.3 The displacements in vertical direction for node 3 (port) and node 4 (starboard) respectively which are at an equal distance from the longitudinal centerline section on horizontal girder of stern transom plate are restrained, i.e.: $\delta_z = 0$.

**3.3.5 Fine mesh analysis**

3.3.5.1 Fine mesh analysis is to be carried out if the result of whole ship FE calculation of stresses in the following areas exceeds 90% of the permissible stress specified in 3.4.1 of this Appendix:

(1) in way of the steps of transverse web frames in cargo hold area;

(2) connection of double bottom girder and transverse bulkhead;

(3) face plate of horizontal girders and large bracket toe in way of the supporting transverse bulkhead;

(4) in way of the bracket toe of longitudinal hatch coaming;

(5) in way of hatch corners of hatch coamings top plates and deck plates;

(6) openings on inner shell, hatch coaming, deck and vertical girder and horizontal girder of transverse bulkheads.

3.3.5.2 Fine mesh analysis is to comply with the requirements of 2.7 of this Appendix.

### 3.4 Yield strength evaluation for global finite element structure of ship

3.4.1 The allowable stress of plates including girder web is as follows:

$$[\sigma_e] = 220/K \quad \text{N/mm}^2$$

where: $K$ — material factor.

3.4.2 The beam element is taken as the axial stress and its allowable stress is as follows:

$$[\sigma] = 220/K \quad \text{N/mm}^2$$

where: $K$ — material factor.

3.4.3 The stress criteria and checking method for fine mesh analysis are defined in 2.7.9 of this Appendix and $[\sigma_e]$ is to be calculated according to 3.4.1.

### 3.5 Buckling strength evaluation for global finite element structure of ship

3.5.1 The buckling strength evaluation for global finite element structure of ship is to be checked in accordance with 2.6.3 of this Appendix.

## 4 Fatigue Strength Evaluation

### 4.1 General requirements

4.1.1 This Section provides methods to evaluate fatigue strength of key positions of container ships under bending and torsional loads.

4.1.2 The wave load calculation for evaluation of fatigue strength of hatch corners is to be based on the equivalent design wave method used for structural analysis of the whole ship, as shown in Section 5 of Chapter 1.

4.1.3 Fatigue damage calculation is based on Palmgren-Miner linear cumulative damage principle, taking into account S-N curves and sea state parameters etc.

4.1.4 In addition to the evaluation method given in this Section, the fatigue evaluation may also be carried out in accordance with relevant requirements of CCS Guidelines for Spectrum-based Fatigue Assessment of Hull Structure.

4.1.5 Hull structures in way of key positions are to be screened based on the result of coarse mesh calculation to determine the fatigue evaluation spots. The evaluation spots are at least to include end bracket toes of longitudinal hatch coaming, hatch corners at the fore (aft) end of engine room, hatch corners at the end of No.1 cargo hold towards the fore end of the ship and a cargo hold hatch corner amidships.

### 4.2 Loads

4.2.1 The loads for fatigue evaluation are to be obtained from the corresponding loading conditions for global analysis of the ship.

4.2.2 The loading condition is to be taken as the full load condition in loading manual where maximum still water bending moment occurs.

4.2.3 Loading conditions

4.2.3.1 In general, the design wave loads to be calculated are as follows:

(1) LC1: maximum vertical wave bending moment in way of 1/2$L$ from $AP$ (hogging);
(2) LC2: minimum vertical wave bending moment in way of 1/2$L$ from $AP$ (sagging);
(3) LC3: maximum horizontal wave bending moment in way of 1/2$L$ from $AP$;
(4) LC4: minimum horizontal wave bending moment in way of 1/2$L$ from $AP$;
(5) LC5: maximum wave torque in way of 1/4$L$ from $AP$;
(6) LC6: minimum wave torque in way of 1/4$L$ from $AP$;
(7) LC7: maximum wave torque in way of 1/2$L$ from $AP$;
(8) LC8: minimum wave torque in way of 1/2$L$ from $AP$;
(9) LC9: maximum wave toque in way of 3/4$L$ from $AP$;
(10) LC10: minimum wave torque in way of 3/4$L$ from $AP$.

4.2.3.2 The displacements and stresses of the global structure are to be obtained by the loading conditions specified in 4.2.3.1 of this Appendix.

4.2.3.3 The range of dynamic stresses at the edge of hatch corners is to be based on the calculation results

of each loading condition specified in 4.2.3.1 of this Appendix and combined as follows:

$$\Delta\sigma_{12} = \sigma_{LC1} - \sigma_{LC2}$$

$$\Delta\sigma_{34} = \sigma_{LC3} - \sigma_{LC4}$$

$$\Delta\sigma_{56} = \sigma_{LC5} - \sigma_{LC6}$$

$$\Delta\sigma_{78} = \sigma_{LC7} - \sigma_{LC8}$$

$$\Delta\sigma_{910} = \sigma_{LC9} - \sigma_{LC10}$$

where: $\Delta\sigma_{ij}$ — range of stresses under the combined load cases *i* and *j*, taken as the range of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm$^2$;

$\sigma_{LCi}$ — value of stress in load case *i*, taken as the value of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm$^2$.

**4.3 Structural modeling**

4.3.1 General requirements

4.3.1.1 The local fine mesh model is to be in accordance with the requirements of 4.3.2 to 4.3.7 of this Appendix .

4.3.1.2 For the fatigue analysis, the three-dimensional fine mesh model of the local structure may be separated for an individual analysis, applying the displacement results obtained from global three-dimensional coarse mesh finite element analysis to the corresponding boundary nodes as boundary conditions for forced displacements. Alternatively, the fine mesh model may be inserted directly into the global model for analysis. The boundary of fine mesh model is as far as practicable to be taken on the structure of primary supporting and web frames, provided that the following model extent is observed.

4.3.2 Fine mesh model of local structure of hatch corners in the midship region

4.3.2.1 For the local fine mesh model of the midship region, the deck openings where the maximum stress or maximum cross-deck strip warping displacement occurs are in general selected, see Figures 4.3.2.1(1) and (2), and the corresponding extent of model is as follows:

(1) for longitudinal extent, half length of a 40 ft container bay, extending forward and afterward of cross deck strip corner;

(2) for vertical extent, from No.2 deck to the top of hatch coaming;

(3) for transverse extent, from the centerline to ship side, covering hatch corners in way of upper deck and the transitional structure of corners in way of hatch coaming top plate.

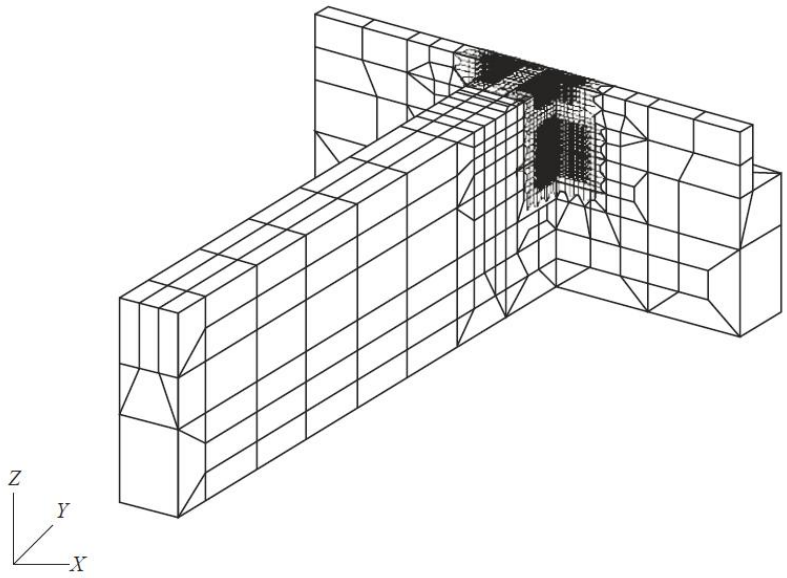



**Figure 4.3.2.1(1) FE Model of Hatch Corners in Way of Cargo Hold Area**

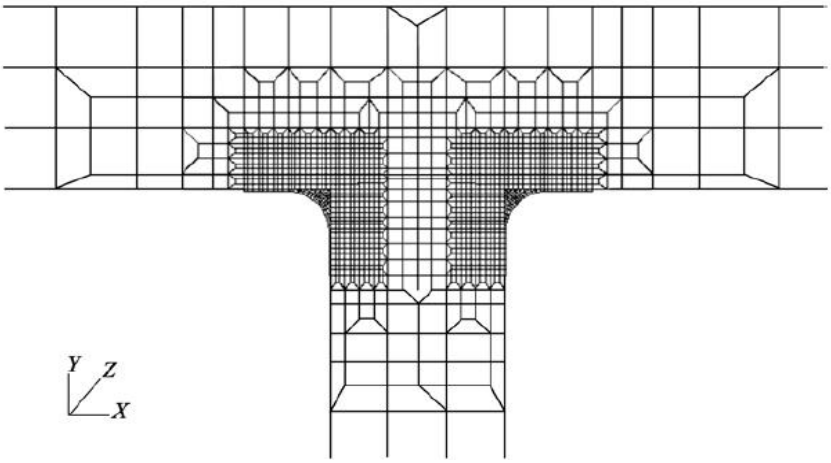



**Figure 4.3.2.1(2) FE Model of Hatch Corners in Way of Cargo Hold Area**
(Upper Deck Hatch Corners Amplified)

4.3.3 Fine mesh model of local structure of hatch corners at fore end of engine room

4.3.3.1 For the local fine mesh model at the fore end of the engine room, the hatch corners at the front bulkhead of the engine room at portside are to be selected, and the corresponding extent of model is as follows:

(1) for longitudinal extent, half length of a 40 ft container bay extending forward from the front transverse bulkhead of the engine room and a similar distance extending afterward to the transverse web frame (in general, at the mesh line of the transverse web frame of the global model);

(2) for vertical extent, from No.2 deck to hatch coaming (in general, up to the first-tier deck in way of superstructures);

(3) for transverse extent, from the centerline to ship side.

4.3.3.2 All the models are to include upper deck structures with openings, radiused transition structures in way of the hatch coaming top plate and the tapered bracket between the forward end of superstructures and hatch coaming, and their geometry is to be described accurately in the model, see Figures 4.3.3.2(1) to (3).

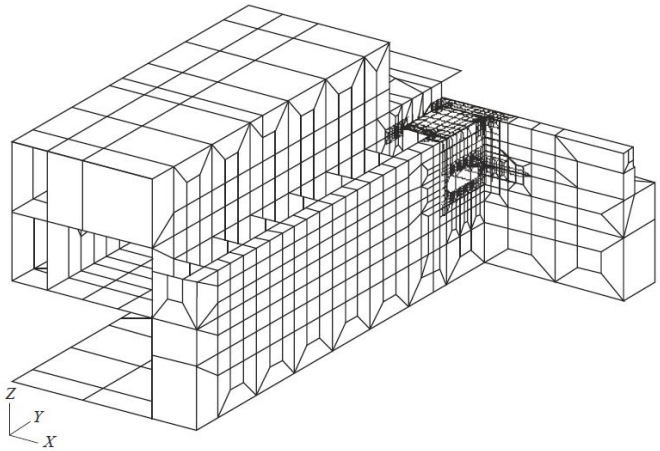



**Figure 4.3.3.2(1) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead**

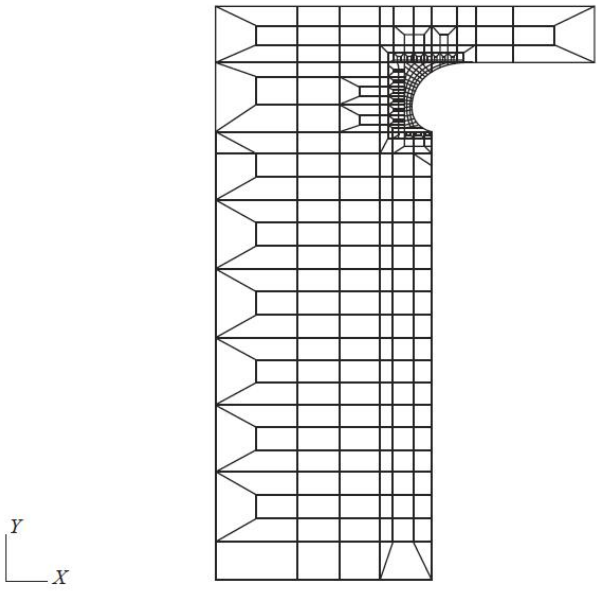



**Figure 4.3.3.2(2) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead**
(Upper Deck Hatch Corners)

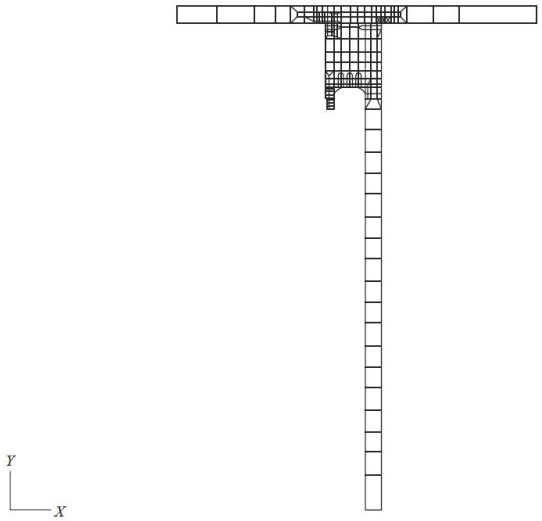



**Figure 4.3.3.2(3) FE Model of Hatch Corner in Way of Engine Room Front Bulkhead**
(Hatch Coaming Top Plate)

4.3.4 The requirements for the local fine mesh model of hatch corners at the aft end of the engine room and the forward end of No.1 cargo hold are the same as those in 4.3.3.1.

4.3.5 Selection of elements and meshing

4.3.5.1 Plate elements are used to simulate primary structural members such as upper deck, shell plate, longitudinal bulkhead and transverse plates, and beam elements are used to simulate longitudinals and stiffeners. Meshing of the positions where hot-spot stress is checked is shown in 4.3.5.4 of this Appendix.

4.3.5.2 The geometry of radiused corners in upper deck area, radiused top plates of hatch coamings, etc. are to be reflected accurately in the fine mesh model, and all openings (ventilators, access openings) are also to be described accurately in the model.

4.3.5.3 Where the tangential stress at the edge of hatch corners can not be obtained from the finite element analysis program, the method of providing virtual rod elements at the edge of hatch corners to obtain the axial stress of elements is to be used to get the tangential stress, and virtual rod elements may be applied to the following positions:

(1) along the radiused edge of hatch corners at the top level of upper deck and hatch coaming;

(2) along the superstructure to the upper edge of the radiused connecting bracket of longitudinal hatch coaming, if any.

4.3.5.4 The plate elements of areas of hot-spot stress evaluation are to be divided in accordance with the

mesh size of plate thickness × plate thickness ($t \times t$). This mesh density is to be maintained within the fine mesh zone, extending at least10$t$ distance in all directions from the center of hot pot stress to provide a smooth transition to the model boundary.

4.3.6 Boundary conditions

4.3.6.1 The boundary conditions for the global three-dimensional coarse mesh FE model are given in 3.3.4 of this Appendix.

4.3.6.2 Where an independent sub-model is used for analysis, the nodal displacements in way of the boundary of a coarse mesh model, which are obtained from calculations of the above-mentioned loading conditions for the global model, are to be transmitted to corresponding nodes of the fine mesh model as forced displacement boundary conditions of the fine mesh model.

**4.4 Fatigue strength evaluation**

4.4.1 Assuming that the long-term distribution of the stress ranges of hull structures is a two-parameter Weibull distribution, the shape parameter $\xi$ of Weibull distribution is to be calculated as follows:

$$\xi = 1.45 - 0.036 f\sqrt{L}$$

where: $L$— length of ship, in m;

$f = 1 - 0.08z/d_1$ for $z \le d_1$;

$f = 0.92+0.08(z - d_1)/(D - d_1)$ for $z > d_1$;

$f = 0.92$ for the calculated point on transverse bulkhead;

$D$ — moulded depth, in m;

$d_1$— draught in the considered condition, in m;

$z$— vertical distance from calculation point to baseline, in m.

4.4.2 Design $S$-$N$ curves are to be selected as follows:

For welding type joint, $D$ curves are selected for fatigue strength evaluation;

For free edge of base metal, C curves are selected for fatigue strength evaluation.

4.4.3 Cumulative damage $D_T$ is to be calculated as follows:

$$D_T = \frac{N_D \alpha}{K} \frac{S_D{}^m}{\left(\ln N_L\right)^{m/\xi}} \mu\Gamma\left(1 + \frac{m}{\xi}\right)$$

where: $N_D$ — total cycles of loads within 20 years' service life of ships, normally taken as $0.65\times10^8$;

$N_L$ — cycles of load spectrum response circle, taken as $10^8$;

$\alpha$ — in-service coefficient of ship, taken as 0.85;

$K$ — S-N curve parameter, see Table 4.4.3(1) of this Appendix;

$S_D$ — design stress ranges, in N/mm$^2$, calculated as follows:

$$S_D = \max\left(f_c \cdot f_{mean} \cdot f_t \cdot \left|\Delta\sigma_{ij}\right|\right)$$

$\Delta\sigma_{ij}$ — design stress ranges of the combined load cases $i$ and $j$, see 4.2.3.3 of this Appendix;

$fc$ — corrosion correction factor, taken as 1.07;

$f_{mean}$ — average stress correction factor, selected as follows:

for welding type joint:

$$f_{mean} = \begin{cases} \min\left(1.0, 0.85 + 0.3\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \ge 0 \\ \max\left(0.7, 0.85 + 0.3\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \le 0 \end{cases}$$

for free edge of base metal

$$f_{mean} = \begin{cases} \min\left(1.0, 0.8 + 0.4\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \ge 0 \\ \max\left(0.6, 0.8 + 0.4\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \le 0 \end{cases}$$

$\sigma_{mean}$ — average stress of considered loading;

$f_t$ — plating thickness correction coefficient, selected as follows:

$$f_t = 1.0 \quad \text{for} \quad t \le 22;$$

$$f_t = \left(\frac{t}{22}\right)^n \text{ for } t > 22;$$

$n$ — coefficient, see Table 4.4.3(2) of this Appendix;

$t$ — plating thickness at hot spot, in mm, taken as the thickness of plating of structure where cracks are easy to occur and extend;

$\xi$ — parameter of Weibull distribution, see 4.4.1 of this Appendix;

$m$ — inverse slope of the *S-N* curve, taken as 3;

$\Gamma$ — complete GAMMA function values, to be calculated as follows:

$$\Gamma(x) = \int_0^\infty u^{x-1} e^{-u} du$$

$$\mu = 1.0 - \frac{\gamma\left(1+\frac{m}{\xi}, \nu\right) - \nu^{-\frac{\nabla m}{\xi}} \gamma\left(1+\frac{m+\nabla m}{\xi}, \nu\right)}{\Gamma\left(1+\frac{m}{\xi}\right)}$$

$$\nu = \left(\frac{S_q}{S_D}\right)^\xi \ln N_L$$

$S_q$ — stress amplitude values at intersection point of two-slope S-N curves, see Table 4.4.3(1) of this Appendix;

$\nabla m$ — difference of inverse slope of two-slope S-N curves, taken as 2;

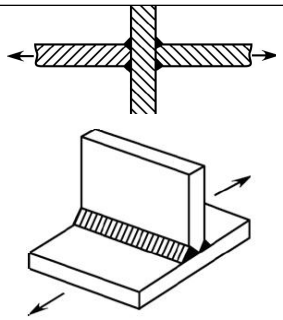
$\gamma(x, \nu)$ — incomplete GAMMA function values, to be calculated as follows:

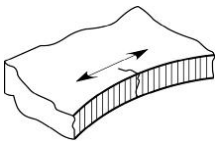
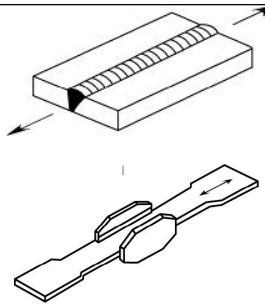
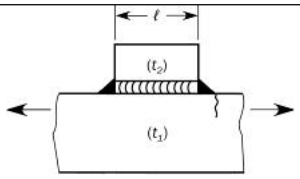
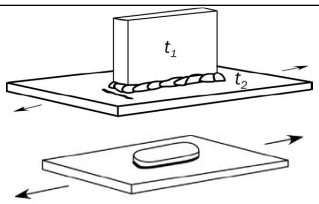
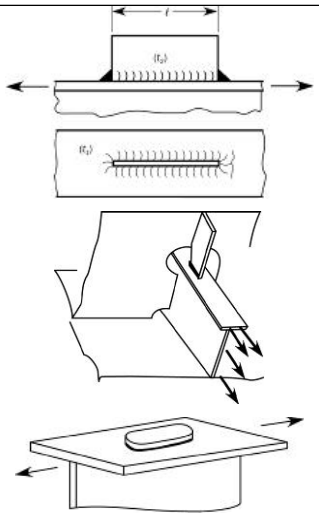
$$\gamma(x, v) = \int_0^v u^{x-1} e^{-u} du$$

Table 4.4.3(1)

| S-N curves | $K$ | $S_q$ |
|---|---|---|
| C | $3.464\times10^{12}$ | 70.2305 |
| D | $1.520\times10^{12}$ | 53.3680 |

Table 4.4.3(2)

| Structural details | Sketches | Coefficient n |
|---|---|---|
| Cruciform joints or transverse T-joints, with weld perpendicular to the direction of load |  | 0.25 |
| Butt joints, with weld perpendicular to the direction of load |  | 0.2 |

| Structural details | Sketches | Coefficient n |
|---|---|---|
| Machine controlled by program or plate with flame-cut edges, with plate edge parallel to the direction of load |  | 0.1 |
| Plate edge which is ground smooth by machine or other means after cutting | | 0 |
| Butt welds, attachments on plate edge, with weld parallel to the direction of load |  | 0.1 |
| Attachments on the flat bar or bulb profile, with weld parallel to the direction of load |   | 0 |
| Bracket welded on the plate, with weld parallel to the direction of load, doubling plate |   | 0.2 |
| T section face plate welded with bracket or doubling plates, with weld parallel to the direction of load |  | 0.1 |

4.4.4 Structure fatigue life is to be calculated as follows:

$$T_F = \frac{20}{D_T}$$

4.4.5 Cumulative damage $D_T$ for structure in its design service life is to meet the following requirement:

$$D_T \leq \frac{20}{T_D}$$

where: $T_D$ — design fatigue life, in year.

# Appendix 3 CALCULATION OF SHEAR FLOW

## 1 General Requirements

This Appendix describes the procedures of direct calculation of shear flow around a ship's cross section due to hull girder vertical shear force. The shear flow $q_v$ at each location in the cross section, is calculated by considering the cross section is subjected to a unit vertical shear force of 1 N in the direction of $Z$ coordinate.

The unit shear flow per mm, $q_v$, in N/mm, is to be taken as:

$$q_v = q_D + q_l$$

where: $q_D$ — determinate shear flow, as defined in 2;

$q_l$ — indeterminate shear flow which circulates around the closed cells, as defined in 3.

In the calculation of the unit shear flow, $q_v$, the longitudinal stiffeners are to be taken into account.

## 2 Determinate Shear Flow

The determinate shear flow, $q_D$, in N/mm at each location in the cross section is to be obtained from the following line integration:

$$q_D(\mathrm{s}) = -\frac{1}{10^6 I_{y-net}} \int_0^s (z - z_n) t_{net} d_s$$

where: $s$ — coordinate value of running coordinate along the cross section, in m;

$I_{y\text{-}net}$ — net moment of inertia of the cross section, in m$^4$;

$t_{net}$ — net thickness of plating, in mm;

$z_n$ — Z coordinate of horizontal neutral axis from baseline, in m.

It is assumed that the cross section is composed of line segments as shown in Figure 1: where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation.

$$q_{Dk} = -\frac{t_{net}\ell}{2 \cdot 10^6 I_{Y-net}} (z_k + z_i - 2z_n) + q_{Di}$$

where: $q_{Dk}, q_{Di}$ — determinate shear flow at node $k$ and node $i$ respectively , in N/mm;

$l$ — length of line segments, in m;

$y_k$, $y_i$ — $Y$ coordinate of the end points $k$ and $i$ of line segment, in m, as defined in Figure 1;

$z_k, z_i$ — $Z$ coordinate of the end points k and i of line segment, in m, as defined in Figure 1.

Where the cross section includes closed cells, the closed cells are to be cut with virtual slits, as shown in Figure 2, in order to obtain the determinate shear flow.

These virtual slits must not be located in walls which form part of another closed cell.

Determinate shear flow at bifurcation points is to be calculated by water flow calculations, or similar, as shown in Figure 2.

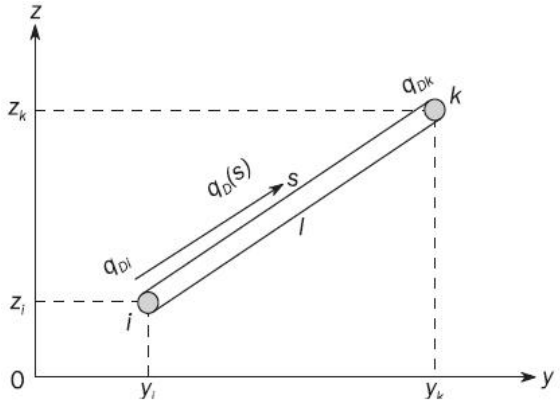



**Figure 1 Definition of line segment**

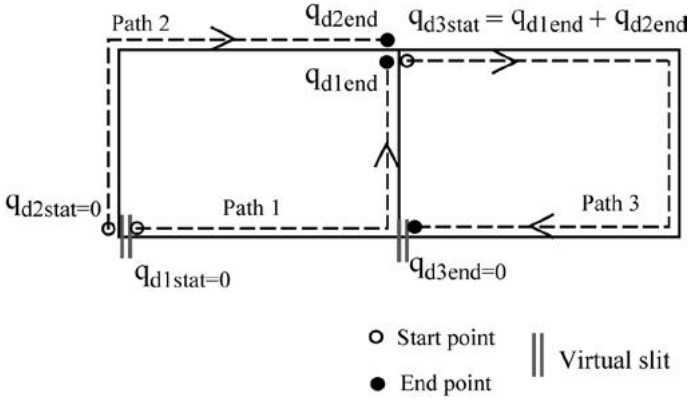



**Figure 2 Calculation of determinate shear flow at bifurcation points**

## 3 Indeterminate Shear Flow

The indeterminate shear flow around closed cells of a cross section is considered as a constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ic} \oint_c \frac{1}{t_{net}} ds - \sum_{m=1}^{N_w} \left( q_{Im} \oint_{c\&m} \frac{1}{t_{net}} ds \right) = - \oint_c \frac{q_D}{t_{net}} ds$$

where: $N_w$ — number of common walls shared by cell $c$ and all other cells;
$c \,\&\, m$ — common wall shared by cells $c$ and $m$;
$q_{Ic}$, $q_{Im}$ — indeterminate shear flow around the closed cell $c$ and $m$ respectively, in N/mm.

Under the assumption of the assembly of line segments shown in Figure 1 and constant plate thickness of each line segment, the above equation can be expressed as follows:

$$q_{Ic} \sum_{j=1}^{N_c} \left( \frac{\ell}{t_{net}} \right)_j - \sum_{m=1}^{N_w} \left\{ q_{Im} \left[ \sum_{j=1}^{N_m} \left( \frac{\ell}{t_{net}} \right)_j \right]_m \right\} = - \sum_{j=1}^{Nc} \phi_j$$

$$\phi_j = \left[ - \frac{\ell^2}{6 \cdot 10^3 I_{Y-net}} (z_k + 2z_i - 3z_n) + \frac{\ell}{t_{net}} q_{Di} \right]_j$$

where: $N_c$ — number of line segments in cell $c$;
$N_m$— number of line segments on the common wall shared by cells $c$ and $m$;
$q_{Di}$— determinate shear flow, in N/mm, calculated according to 2.

The difference in the directions of running coordinates specified in 2 and in this section has to be considered.

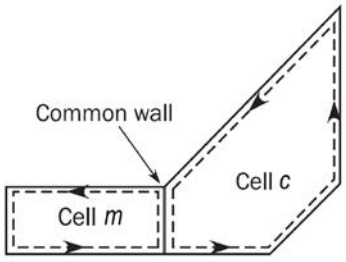



**Figure 3 Closed cells and common wall**

## 4 Computation of Sectional Properties

Properties of the cross section are to be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$\ell = \sqrt{\left(y_k - y_i\right)^2 + \left(z_k - z_i\right)^2}$$

$$a_{net} = 10^{-3}\ell t_{net} \qquad A_{net} = \sum a_{net}$$

$$s_{y-net} = \frac{a_{net}}{2}(z_k + z_i) \qquad S_{y-net} = \sum s_{y-net}$$

$$i_{y0-net} = \frac{a_{net}}{3}\left(z_k^2 + z_k z_i + z_i^2\right) \qquad I_{y0-net} = \sum i_{y0-net}$$

where: $a_{net}$, $A_{net}$ — area of the line segment and the cross section respectively, in m$^2$;

$s_{y\text{-}net}$, $S_{y\text{-}net}$ — first moment of the line segment and the cross section about the baseline, in m$^3$;

$i_{y0\text{-}net}$, $I_{y0\text{-}net}$ — moment of inertia of the line segment and the cross section about the baseline, in m$^4$.

The height of horizontal neutral axis, $z_n$, in m, is to be obtained as follows:

$$z_n = \frac{S_{y-net}}{A_{net}}$$

Inertia moment about the horizontal neutral axis, in m$^4$, is to be obtained as follows:

$$I_{y-net} = I_{y0-net} - z_n^2 A_{net}$$

# Appendix 4 BUCKLING CAPACITY

**Symbols**

*x axis :* local axis of a rectangular buckling panel parallel to its long edge;
*y axis :* local axis of a rectangular buckling panel perpendicular to its long edge;
$\sigma_x$ : membrane stress applied in *x* direction, in N/mm²;
$\sigma_y$ : membrane stress applied in *y* direction, in N/mm²;
$\tau$ : membrane shear stress applied in *xy* plane, in N/mm²;
$\sigma_a$ : axial stress in the stiffener, in N/mm²;
$\sigma_b$ : bending stress in the stiffener, in N/mm²;
$\sigma_w$ : warping stress in the stiffener, in N/mm²;
$\sigma_{cx}, \sigma_{cy}, \tau_c$: critical stress, in N/mm², defined in 2.1.1 of this Appendix for plates;
$R_{eH_S}$ : specified minimum yield stress of the stiffener, in N/mm²;
$R_{eH_P}$ : specified minimum yield stress of the plate, in N/mm²;
$a$ : length of the longer side of the plate panel as shown in Table 2, in mm;
$b$ : length of the shorter side of the plate panel as shown in Table 2, in mm;
$d$ : length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in Table 3, in mm;
$\sigma_E$ : elastic buckling reference stress, in N/mm², to be taken as:

(1) for the application of plate limit state according to 2.1.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2;$$

(2) for the application of curved plate panels according to 2.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2;$$

ν : Poisson's ratio to be taken equal to 0.3;
$t_p$: net thickness of plate panel, in mm;
$t_w$: net stiffener web thickness, in mm;
$t_f$: net flange thickness, in mm;
$b_f$: breadth of the stiffener flange, in mm;
$h_w$: stiffener web height, in mm;
$e_f$ : Distance from attached plating to centre of flange, in mm, to be taken as:

(1) $e_f = h_w$ for flat bar profile;
(2) $e_f = h_w - 0.5\ t_f$ for bulb profile;
(3) $e_f = h_w + 0.5\ t_f$ for angle and Tee profiles;

$\alpha$: aspect ratio of the plate panel, to be taken as:

$$\alpha = \frac{a}{b}$$

$\beta$: coefficient, to be taken as:

$$\beta = \frac{1-\psi}{\alpha}$$

$\psi$: edge stress ratio, to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

$\sigma_1$ : maximum stress, in N/mm²;
$\sigma_2$ : minimum stress, in N/mm²;
$R$ : radius of curved plate panel, in mm;
$\ell$ : span, in mm, of stiffener equal to the spacing between primary supporting members;
$S$ : spacing of stiffener, in mm;
$\omega$: factor, to be taken as $\omega = \min(3; \alpha)$.

## 1 Elementary Plate Panel (EPP)

### 1.1 Definition

An Elementary Plate Panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary

supporting members.
All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates (usually longitudinal stiffened panels in deck, bottom and inner-bottom plating, shell and longitudinal bulkheads).

### 1.2 EPP with different thicknesses

1.2.1 Longitudinally stiffened EPP with different thicknesses

In longitudinal stiffening arrangement, when the plate thickness varies over the width, $b$, in mm, of a plate panel, the buckling capacity is calculated on an equivalent plate panel width, having a thickness equal to the smaller plate thickness, $t_1$. The width of this equivalent plate panel, $b_{eq}$, in mm, is defined by the following formula:

$$b_{eq}=\ell_1+\ell_2\left(\frac{t_1}{t_2}\right)^{1.5}$$

where:

$\ell_1$ : width of the part of the plate panel with the smaller plate thickness, $t_1$, in mm, as defined in Figure 1;

$\ell_2$ : width of the part of the plate panel with the greater plate thickness, $t_2$, in mm, as defined in Figure 1.

Where a panel is consisted of different materials, the minimum yield strength is to be used in buckling assessment.

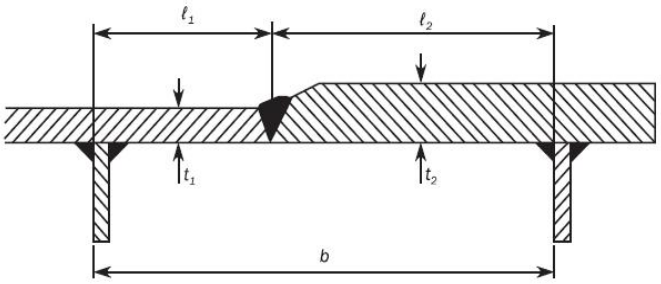



**Figure 1 Plate thickness change over the width**

1.2.2 Transversally stiffened EPP with different thicknesses

In transverse stiffening arrangement, when an EPP is made of different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP. The applied stress and lateral pressure is to be measured from the load calculation point of the plate panel.

## 2 Buckling Capacity of Plates

### 2.1 Plate panel

2.1.1 Plate limit state

The plate limit state is based on the following interaction formulae. Buckling check under normal stress is for the compression stress, when the normal stress ($\sigma_x$, $\sigma_y$) is less than zero, the corresponding item is to be deleted and pure shear buckling is to be checked:

(a) longitudinal stiffening arrangement:

$$\left(\frac{\gamma_C\sigma_x}{\sigma_{cx}}\right)^{2/\beta_p^{0.25}}+\left(\frac{\gamma_C|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}}=1$$

(b) transverse stiffening arrangement:

$$\left(\frac{\gamma_C\sigma_y}{\sigma_{cy}}\right)^{2/\beta_p^{0.25}}+\left(\frac{\gamma_C|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}}=1$$

where:

$\sigma_x, \sigma_y$ — applied normal stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

$\tau$ — applied shear stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

$\sigma_{cx}$ — ultimate buckling stress, in N/mm², in direction parallel to the longer edge of buckling panel as defined in 2.1.3 of this Appendix;

$\sigma_{cy}$ — ultimate buckling stress, in N/mm², in direction parallel to the shorter edge of buckling panel as defined in 2.1.3 of this Appendix;

$\tau_c$ — ultimate buckling shear stress, in N/mm², as defined in 2.1.3 of this Appendix;

$\beta_p$ — plate slenderness parameter, to be taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$$

2.1.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where:

$K$ — buckling factor, as defined in Table 2 and Table 3.

2.1.3 Ultimate buckling stresses

The ultimate buckling stress of plate panels, in N/mm², is to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm², is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where:

$C_x, C_y, C_\tau$ — reduction factors, as defined in Table 2.

The boundary conditions for plates are to be considered as simply supported (see cases 1, 2 and 15 of Table 2). If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 2 subject to the agreement.

2.1.4 Correction factor $F_{long}$

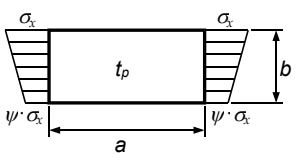
The correction factor $F_{long}$ depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 1. An average value of $F_{long}$ is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 1, the value of $c$ is to be agreed. In such a case, value of $c$ higher than those mentioned in Table 1 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate.

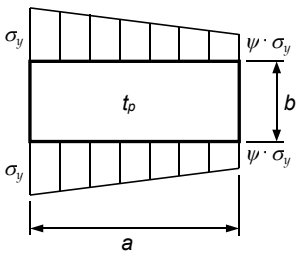
**Correction factor $F_{long}$** **Table 1**

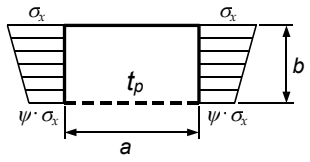
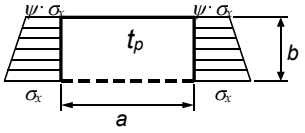
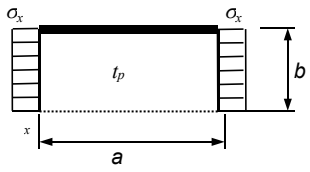
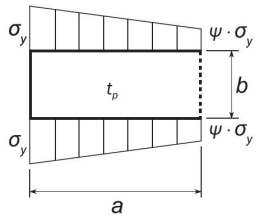
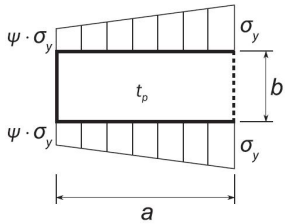
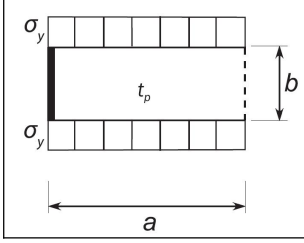
| Structural element types | | | $F_{long}$ | $c$ |
|---|---|---|---|---|
| Unstiffened Panel | | | 1.0 | N/A |
| Stiffened panel | Stiffener not fixed at both ends | | 1.0 | N/A |
| | Stiffener fixed at both ends | Flat bar (1) | $F_{long}=c+1$ for $\frac{t_w}{t_p}>1$ | 0.1 |
| | | Bulb profile | | 0.3 |
| | | Angle profile | | 0.4 |
| | | T profile | $F_{long}=c\left(\frac{t_w}{t_p}\right)^3+1$ for $\frac{t_w}{t_p}\le 1$ | 0.3 |
| | | Girder of high rigidity (e.g. bottom transverse) | 1.4 | N/A |
| | | | | |

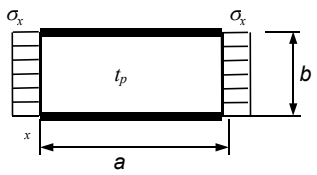
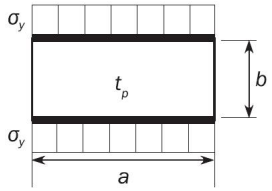
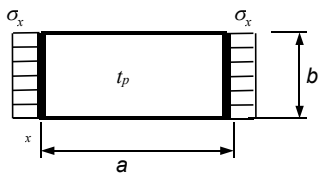
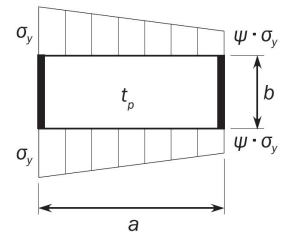
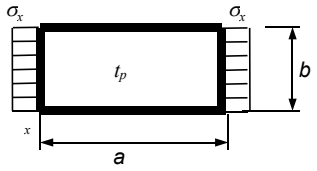
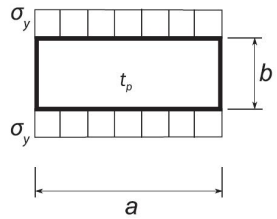
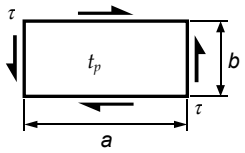
Note: (1) $t_w$ is the net web thickness, in mm, without the correction defined in 4.3.5 of this Appendix.

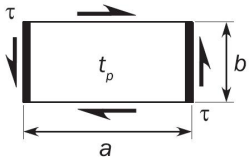
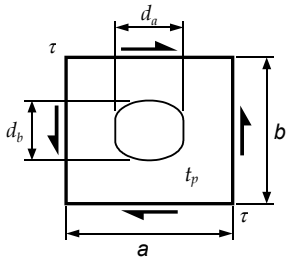
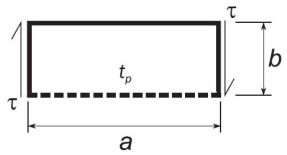
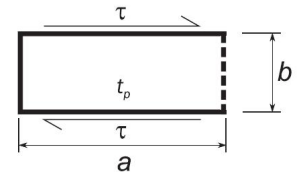
**Buckling factor and reduction factor for plane plate panels** **Table 2**

| Case | Stress ratio $\psi$ | Aspect ratio $\alpha$ | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|---|
| 1   | $1 \ge \psi \ge 0$ | | $K_x = F_{long}\frac{8.4}{\psi + 1.1}$ | $C_x = 1$ for $\lambda \le \lambda_c$<br>$C_x = c\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$<br>where: |
| | $0 > \psi > -1$ | | $K_x = F_{long}\left[7.63 - \psi\,(6.26 - 10\,\psi)\right]$ | |

| Case | Stress ratio $\psi$ | Aspect ratio $\alpha$ | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|---|
| | $\psi \le -1$ | $K_x = F_{long}\left[5.975\ (1-\psi)^2\right]$ | | $c = (1.25 - 0.12\psi) \le 1.25$<br>$\lambda_c = \frac{c}{2}\left(1+\sqrt{1-\frac{0.88}{c}}\right)$ |
| 2<br>  <br> | $1 \ge \psi \ge 0$ | $K_y = \frac{2\left(1+\frac{1}{\alpha^2}\right)^2}{1+\psi+\frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2}+6.9 f_1\right)}$ | | $C_y = c\left(\frac{1}{\lambda}-\frac{R+F^2(H-R)}{\lambda^2}\right)$<br>where:<br>$c = (1.25 - 0.12\psi) \le 1.25$<br>$R = \lambda(1-\lambda/c)$ for $\lambda < \lambda_c$<br>$R = 0.22$ for $\lambda \ge \lambda_c$<br>$\lambda_c = 0.5\,c\left(1+\sqrt{1-0.88/c}\right)$<br>$F = \left(1-\left(\frac{K}{0.91}-1\right)/\lambda_p^2\right)c_1 \ge 0$<br>$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$<br>$c_1 = \left(1-\frac{1}{\alpha}\right) \ge 0$<br>$H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \ge R$<br>$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$ |
| | | $\alpha \le 6$ | $f_1 = (1-\psi)(\alpha-1)$ | |
| | | $\alpha > 6$ | $f_1 = 0.6\left(1-\frac{6\psi}{\alpha}\right)\left(\alpha+\frac{14}{\alpha}\right)$ but not greater than $14.5-\frac{0.35}{\alpha^2}$ | |
| | $0 > \psi \ge 1-4\alpha/3$ | $K_y = \frac{200(1+\beta^2)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$ | | |
| | | $\alpha > 6(1-\psi)$ | $f_1 = 0.6\left(\frac{1}{\beta}+14\beta\right)$ but not greater than $14.5-0.35\beta^2$<br>$f_2 = f_3 = 0$ | |
| | | $3(1-\psi) \le \alpha \le 6(1-\psi)$ | $f_1 = \frac{1}{\beta}-1$<br>$f_2 = f_3 = 0$ | |
| | | $1.5(1-\psi) \le \alpha < 3(1-\psi)$ | $f_1 = \frac{1}{\beta}-(2-\omega\beta)^4-9(\omega\beta-1)\left(\frac{2}{3}-\beta\right)$<br>$f_2 = f_3 = 0$ | |
| | | $1-\psi \le \alpha < 1.5(1-\psi)$ | For $\alpha > 1.5$:<br>$f_1 = 2\left(\frac{1}{\beta}-16\left(1-\frac{\omega}{3}\right)^4\right)\left(\frac{1}{\beta}-1\right)$<br>$f_2 = 3\beta - 2$<br>$f_3 = 0$<br>For $\alpha \le 1.5$:<br>$f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$<br>$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$<br>$f_3 = 0$<br>$f_4 = (1.5\text{-}Min(1.5;\alpha))^2$ | |
| | | $0.75(1-\psi) \le \alpha < 1-\psi$ | $f_1 = 0$<br>$f_2 = 1+2.31(\beta-1)-48\left(\frac{4}{3}-\beta\right)f_4^2$<br>$f_3 = 3f_4(\beta-1)\left(\frac{f_4}{1.81}-\frac{\alpha-1}{1.31}\right)$<br>$f_4 = (1.5\text{-}Min(1.5;\alpha))^2$ | |

| Case | Stress ratio $\psi$ | Aspect ratio $\alpha$ | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|---|
| | $\psi < 1\text{-}4\alpha/3$ | | $K_y = 5.972\dfrac{\beta^2}{1-f_3}$<br>where:<br>$f_3 = f_5\left(\dfrac{f_5}{1.81}+\dfrac{1+3\psi}{5.24}\right)$<br>$f_5 = \dfrac{9}{16}(1+Max(-1;\psi))^2$ | |
| 3<br>  | $1 \geq \psi \geq 0$ | | $K_x = \dfrac{4(0.425+1/\alpha^2)}{3\psi+1}$ | $C_x = 1$ for $\lambda \leq 0.7$<br>$C_x = \dfrac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$ |
| | $0 > \psi \geq -1$ | | $K_x = 4(0.425+1/\alpha^2)(1+\psi) - 5\psi(1-3.42\psi)$ | |
| 4<br>  | $1 \geq \psi \geq -1$ | | $K_x = \left(0.425+\dfrac{1}{\alpha^2}\right)\dfrac{3-\psi}{2}$ | |
| 5<br>  | | $\alpha \geq 1.64$ | $K_x = 1.28$ | |
| | | $\alpha < 1.64$ | $K_x = \dfrac{1}{\alpha^2}+0.56+0.13\alpha^2$ | |
| 6<br>  | $1 \geq \psi \geq 0$ | | $K_y = \dfrac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$ | $C_y = 1$ for $\lambda \leq 0.7$<br>$C_y = \dfrac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$ |
| | $0 > \psi \geq -1$ | | $K_y = 4(0.425+\alpha^2)(1+\psi)\dfrac{1}{\alpha^2} - 5\psi(1-3.42\psi)\dfrac{1}{\alpha^2}$ | |
| 7<br>  | $1 \geq \psi \geq -1$ | | $K_y = (0.425+\alpha^2)\dfrac{(3-\psi)}{2\alpha^2}$ | |
| 8<br>  | – | | $K_y = 1+\dfrac{0.56}{\alpha^2}+\dfrac{0.13}{\alpha^4}$ | |

| Case | Stress ratio $\psi$ | Aspect ratio $\alpha$ | Buckling factor $\boldsymbol{K}$ | Reduction factor $\boldsymbol{C}$ |
|---|---|---|---|---|
| 9<br>  | – | $K_x = 6.97$ | | $C_x = 1$ for $\lambda \le 0.83$<br>$C_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$ |
| 10<br>  | – | $K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$ | | |
| 11<br>  | – | $\alpha \ge 4$ | $K_x = 4$ | |
| | | α < 4 | $K_x = 4 + 2.74\left(\frac{4-\alpha}{3}\right)^4$ | |
| 12<br>  | – | $K_y$ determined as per case 2 | | • For α < 2: $C_y = C_{y2}$<br>• For α ≥ 2: $C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$<br>where:<br>$C_{y2} = C_y$ (determined as per case 2) |
| 13<br>  | – | $\alpha \ge 4$ | $K_x = 6.97$ | $C_x = 1$ for $\lambda \le 0.83$<br>$C_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$ |
| | | α < 4 | $K_x = 6.97 + 3.1\left(\frac{4-\alpha}{3}\right)^4$ | |
| 14<br>  | – | $K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2}\left[\frac{4 - 1/\alpha}{3}\right]^4$ | | $C_y = 1$ for $\lambda \le 0.83$<br>$C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$ |
| 15<br>  | – | $K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$ | | $C_\tau = 1$ for $\lambda \le 0.84$<br>$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$ |

| Case | Stress ratio $\psi$ | Aspect ratio $\alpha$ | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|---|
| 16<br>  <br> | – | | $K_\tau = \sqrt{3}\left\{5.34 + Max\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right\}$ | |
| 17<br>  <br> | – | | $K = K'r$<br>$K'$ = $K$ according to case 15<br>$r$ = opening reduction factor taken as:<br>$r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$<br>with<br>$\frac{d_a}{a} \le 0.7$ and $\frac{d_b}{b} \le 0.7$ | |
| 18<br>  <br> | – | | $K_\tau = 3^{0.5}\left(0.6 + 4/\alpha^2\right)$ | $C_\tau = 1$ for $\lambda \le 0.84$<br>$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$ |
| 19<br>  <br> | – | | $K_\tau = 8$ | |
| Edge boundary conditions:<br>- - - - - - - - - Plate edge free<br>————— Plate edge simply supported<br>━━━━━ Plate edge clamped. | | | | |
| Note:<br>(1) Cases listed are general cases. Each stress component ($\sigma_x$, $\sigma_y$) is to be understood in local coordinates. | | | | |

## 2.2 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \le 2500$. Otherwise, the requirement for plate limit state given in 2.1.1 of this Appendix is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax}}{C_{ax} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3}}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

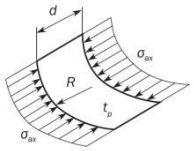
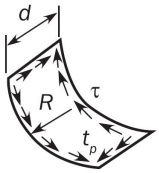
where:

$\sigma_{ax}$ — applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm². In case of tensile axial stresses, $\sigma_{ax}$= 0;

$C_{ax}$, $C_\tau$ — buckling reduction factor of the curved plate panel, as defined in Table 3.

The stress multiplier factor $\gamma_c$ of the curved plate panel needs not be taken less than the stress multiplier factor $\gamma_c$ for the expanded plane panel according to 2.1.1 of this Appendix.

**Buckling Factor and reduction factor for curved plate panel with $R/t_p \leq 2500$ Table 3**

| Case | Aspect ratio | Buckling factor $K$ | Reduction factor $C$ |
|---|---|---|---|
| 1  | $\frac{d}{R} \leq 0.5\sqrt{\frac{R}{t_p}}$ | $K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$ | For general application:<br>$C_{ax} = 1$ for $\lambda \leq 0.25$<br>$C_{ax} = 1.233\text{-}0.933\lambda$ for $0.25<\lambda\leq 1$<br>$C_{ax} = 0.3/\lambda^3$ for $1<\lambda\leq 1.5$<br>$C_{ax} = 0.2/\lambda^2$ for $\lambda>1.5$<br>For curved single fields, e.g. bilge strake, which are bounded by plane panels:<br>$C_{ax} = 0.65/\lambda^2 \leq 1.0$ |
| | $\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$ | $K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \geq 0.4\frac{d^2}{Rt_p}$ | |
| 2  | $\frac{d}{R} \leq 8.7\sqrt{\frac{R}{t_p}}$ | $K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$ | $C_\tau = 1$ for $\lambda \leq 0.4$<br>$C_\tau = 1.274 - 0.686\lambda$ for $0.4 < \lambda \leq 1.2$<br>$C_\tau = 0.65/\lambda^2$ for $\lambda > 1.2$ |
| | $\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$ | $K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$ | |
| Explanations for boundary conditions:<br>——— Plate edge simply supported. | | | |

## 3 Buckling Capacity of Overall Stiffened Panel

The elastic stiffened panel limit state is based on the following interaction formula:

$$\frac{P_Z}{c_f} = 1$$

where: $P_z$ and $c_f$ are defined in 4.4.3 of this Appendix.

## 4 Buckling Capacity of Longitudinal Stiffeners

### 4.1 Stiffeners limit states

The buckling capacity of longitudinal stiffeners is to be checked for the following limit states:
(1) stiffener induced failure (SI);
(2) associated plate induced failure (PI).

### 4.2 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment of longitudinal stiffeners.

### 4.3 Stiffener idealization

4.3.1 Effective length of the stiffener $l_{eff}$

The effective length of the stiffener $l_{eff}$ in mm, is to be taken equal to:

(1) $l_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $l_{eff} = 0.75l$ for stiffener simply supported at one end and fixed at the other;

(3) $l_{eff} = l$ for stiffener simply supported at both ends.

4.3.2 Effective width of the attached plating $b_{eff1}$

The effective width of the attached plating of a stiffener $b_{eff1}$, in mm, without the shear lag effect is to be taken equal to:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

where:

$C_{x1}$, $C_{x2}$ — reduction factor defined in Table 2 calculated for each side of the considered stiffener according to case 1;

$b_1$, $b_2$ — width of plate panel on each side of the considered stiffener, in mm.

4.3.3 Effective width of attached plating $b_{eff}$

The effective width of attached plating of stiffeners, $b_{eff}$, in mm, is to be taken as:

$$b_{eff} = min\left(b_{eff1}, \chi_s s\right)$$

where:

$\chi_s$ — effective width coefficient to be taken as:

- $\chi_s = min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}}; 1\right]$ for $\frac{\ell_{eff}}{s} \geq 1$
- $\chi_s = 0.407\frac{\ell_{eff}}{s}$ for $\frac{\ell_{eff}}{s} < 1$

4.3.4 Net thickness of attached plating $t_p$

The net thickness of plate $t_p$, in mm, is to be taken as the mean thickness of the two attached plating panels.

4.3.5 Effective web thickness of flat bar

For accounting the decrease of stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used for the calculation of the net sectional area, $A_s$, the net section modulus, $Z$, and the moment of inertia, $I$, of the stiffener and is taken as:

$$t_{w_red} = t_w\left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1 - \frac{b_{eff1}}{s}\right)\right)$$

4.3.6 Net section modulus $Z$ of a stiffener

The net section modulus $Z$ of a stiffener, in cm$^3$, including effective width of plating $b_{eff}$ is to be taken equal to:

(1) the section modulus calculated at the top of stiffener flange for stiffener induced failure (SI).

(2) the section modulus calculated at the attached plating for plate induced failure (PI).

4.3.7 Net moment of inertia $I$ of a stiffener

The net moment of inertia $I$, in cm$^4$, of a stiffener including effective width of attached plating $b_{eff}$ is to comply with the following requirement:

$$I \geq \frac{s\, t_p^{\,3}}{12{\cdot}10^4}.$$

4.3.8 Idealisation of bulb profile

Bulb profiles may be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where: $h'_w$, $t'_w$ — net height and thickness of a bulb section, in mm, as shown in Figure 2;

$\alpha$ — coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for} \quad h'_w \leq 120$$

$$\alpha = 1.0 \quad \text{for} \quad h'_w > 120$$

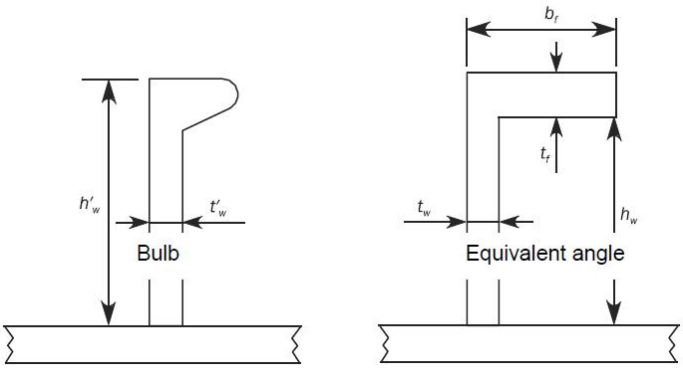



**Figure 2 Idealisation of bulb stiffener**

### 4.4 Ultimate buckling capacity

4.4.1 Longitudinal stiffener limit state

When $\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} = 1$$

where:

$\sigma_a$ — effective axial stress, in N/mm², at mid-span of the stiffener, defined in 4.4.2 of this Appendix;

$\sigma_b$ — bending stress in the stiffener, in N/mm², defined in 4.4.3 of this Appendix;

$\sigma_w$ — stress due to torsional deformation, in N/mm², defined in 4.4.4 of this Appendix;

$R_{eH}$ — specified minimum yield stress of the material, in N/mm²:

(1) $R_{eH} = R_{eH_S}$ for stiffener induced failure (SI);

(2) $R_{eH} = R_{eH_P}$ for plate induced failure (PI).

4.4.2 Effective axial stress $\sigma_a$

The effective axial stress $\sigma_a$, in N/mm², at mid-span of the stiffener, acting on the stiffener with its attached plating is to be taken equal to:

$$\sigma_a = \sigma_x \frac{s t_p + A_s}{b_{eff1} t_p + A_s}$$

where:

$\sigma_x$ — nominal axial stress, in N/mm², acting on the stiffener with its attached plating, calculated according to 7.2.4.4.1 a) of this Chapter;

$A_s$ — net sectional area, in mm², of the considered stiffener.

4.4.3 Bending stress $\sigma_b$

The bending stress in the stiffener $\sigma_b$, in N/mm², is to be taken equal to:

$$\sigma_b = \frac{M_o + M_1}{1000\, Z}$$

where:

$M_1$ — bending moment, in Nmm, due to the lateral load $P$:

(1) $M_1 = C_i \frac{|P| s \ell^2}{24 \cdot 10^3}$ for continuous stiffener;

(2) $M_1 = C_i \frac{|P| s \ell^2}{8 \cdot 10^3}$ for sniped stiffener;

$P$ — lateral load, in kN/m², to be equal to the static pressure at the load calculation point of the stiffener;

$C_i$ — pressure coefficient;

(1) $C_i = C_{SI}$ for stiffener induced failure (SI);

(2) $C_i = C_{PI}$ for plate induced failure (PI);

$C_{PI}$ — plate induced failure pressure coefficient:

(1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI}=-1$ if the lateral pressure is applied on the same side as the stiffener;

$C_{SI}$ — stiffener induced failure pressure coefficient:

(1) $C_{SI}=-1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI}=1$ if the lateral pressure is applied on the same side as the stiffener;

$M_0$ — bending moment, in Nmm, due to the lateral deformation $w$ of stiffener:

$$M_0 = F_E\left(\frac{P_z w}{c_f - P_z}\right), \text{ with } c_f - P_z > 0;$$

$F_E$ — ideal elastic buckling force of the stiffener, in N:

$$F_E=\left(\frac{\pi}{\ell}\right)^2 EI\cdot 10^4;$$

$P_z$ — normal lateral load, in N/mm$^2$, acting on stiffeners due to stresses $\sigma_x$, $\sigma_y$ and $\tau$, in the attached plating in way of stiffener mid span:

$$P_z=\frac{t_p}{s}\left(\sigma_{xl}\left(\frac{\pi s}{\ell}\right)^2+\sqrt{2}\,\tau_1\right);$$

$$\sigma_{x\ell} = \gamma_c\sigma_x\left(1+\frac{A_s}{st_p}\right), \text{ but not less than 0;}$$

$$\tau_1=\gamma|\tau|-t_p\sqrt{R_{eH_P}\,E\left(\frac{m_1}{a^2}+\frac{m_2}{b^2}\right)}, \text{ but not less than 0;}$$

$m_1$, $m_2$ — coefficients, taken equal to:

(1) $m_1 = 1.47$, $m_2 = 0.49$ for $\alpha\geq 2$;

(2) $m_1 = 1.96$, $m_2 = 0.37$ for $\alpha<2$;

$w$ — deformation of stiffener, in mm, taken equal to:

$$w = w_0 + w_1;$$

$w_0$ — assumed imperfection, in mm, taken equal to:

(1) $w_0=\ell/1000$ in general;

(2) $w_0=-w_{na}$ for stiffeners sniped at both ends, considering stiffener induced failure (SI);

(3) $w_0=w_{na}$ for stiffeners sniped at both ends, considering plate induced failure (PI);

$w_{na}$ — distance, in mm, from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating;

$w_1$ — deformation of stiffener at midpoint of stiffener span due to lateral load $P$, in mm. In case of uniformly distributed load, $w_1$ is to be taken as:

(1) $w_1=C_i\frac{|P|\,s\,\ell^4}{384\cdot 10^7 E\,I}$ in general;

(2) $w_1=C_i\frac{5|P|\,s\,\ell^4}{384\cdot 10^7 E\,I}$ for stiffener sniped at both ends;

$c_f$ — elastic support provided by the stiffener, in N/mm$^2$, to be taken equal to:

$$c_f=F_E\left(\frac{\pi}{\ell}\right)^2(1+c_p);$$

$c_p$ — coefficient, to be taken as:

$$c_p=\frac{1}{1+\frac{0.91}{c_{xa}}\left(\frac{12I}{st_p^3}10^4-1\right)}$$

$c_{xa}$ — coefficient, to be taken as:

(1) $c_{xa}=\left[\frac{\ell}{2s}+\frac{2s}{\ell}\right]^2$ for $\ell\geq 2s$;

(2) $c_{xa}=\left[1+\left(\frac{\ell}{2s}\right)^2\right]^2$ for $\ell<2s$.

4.4.4 Stress due to torsional deformation $\sigma_w$

The stress due to torsional deformation $\sigma_w$, in N/mm$^2$, is to be taken equal to:

(1) $\sigma_w = Ey_w\left(\frac{t_f}{2} + h_w\right)\Phi_0\left(\frac{\pi}{\ell}\right)^2\left(\frac{1}{1 - \frac{0.4R_{eH_S}}{\sigma_{ET}}} - 1\right}$ for stiffener induced failure (SI);

(2) $\sigma_w = 0$ for plate induced failure (PI).

where:

$y_W$ — distance, in mm, from centroid of stiffener cross-section to the free edge of stiffener flange, to be taken as:

(1) $y_w = \frac{t_w}{2}$ for flat bar;

(2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;

(3) $y_w = \frac{b_f}{2}$ for Tee profile;

$\Phi_0$ — coefficient, to be taken as:

$\Phi_0 = \frac{\ell}{h_w}10^{-3}$;

$\sigma_{ET}$ — reference stress for torsional buckling, in N/mm$^2$:

$\sigma_{ET} = \frac{E}{I_p}\left(\frac{\varepsilon\pi^2 I_\omega 10^2}{\ell^2} + 0.385 I_T\right)$

$I_p$ — net polar moment of inertia of the stiffener about point *C* as shown in Figure 3, as defined in Table 4, in cm$^4$;

$I_T$ — net St. Venant's moment of inertia of the stiffener, as defined in Table 4, in cm$^4$;

$I_\omega$ — net sectional moment of inertia of the stiffener about point *C* as shown in Figure 3, as defined in Table 4, in cm$^6$;

$\varepsilon$ — degree of fixation, to be taken as:

$$\varepsilon = 1 + \frac{\left(\frac{\ell}{\pi}\right)^2 10^{-3}}{\sqrt{I_\omega\left(\frac{0.75s}{t_p^3} + \frac{e_f - 0.5t_f}{t_w^3}\right)}}.$$

**Moments of inertia** **Table 4**

| Characteristics of cross section | Flat bars | Bulb, angle and Tee profiles |
|---|---|---|
| $I_P$ | $\frac{h_w^3 t_w}{3\cdot 10^4}$ | $\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2\right)10^{-4}$ |
| $I_T$ | $\frac{h_w t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$ | $\frac{(e_f - 0.5t_f)t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right)$ + $\frac{b_f t_f^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$ |
| $I_\omega$ | $\frac{h_w^3 t_w^3}{36\cdot 10^6}$ | $\frac{A_f e_f^2 b_f^2}{12\cdot 10^6}\left(\frac{A_f + 2.6A_w}{A_f + A_w}\right)$ for bulb and angle profiles<br>$\frac{b_f^3 t_f e_f^2}{12\cdot 10^6}$ for Tee profiles |
| $A_w$: net web area, in mm$^2$;<br>$A_f$: net flange area, in mm$^2$. | | |

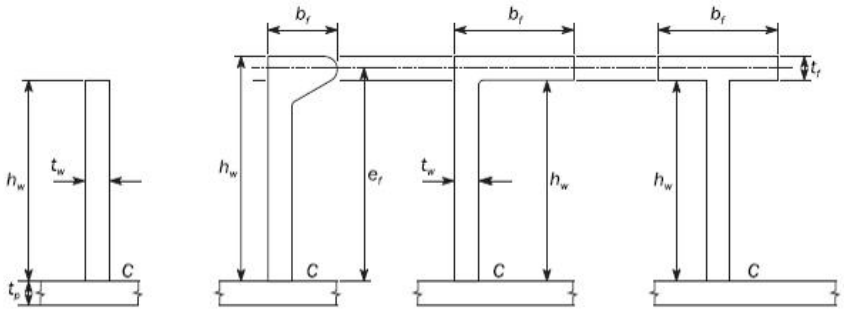



**Figure 3 Stiffener cross sections**

# Appendix 5 HULL GIRDER ULTIMATE BENDING CAPACITY

**Symbols**

$I_{y\text{-}net}$: net moment of inertia, in $m^4$, of the hull transverse section around its horizontal neutral axis;

$Z_{B\text{-}net}$, $Z_{D\text{-}net}$: section moduli, in $m^3$, at bottom and deck, respectively;

$R_{eH_S}$: minimum yield stress, in $N/mm^2$, of the material of the considered stiffener;

$R_{eH_P}$: minimum yield stress, in $N/mm^2$, of the material of the considered plate;

$A_{s\text{-}net}$: net sectional area, in $cm^2$, of stiffener, without attached plating;

$A_{p\text{-}net}$: net sectional area, in $cm^2$, of attached plating.

## 1 General Assumptions

1.1 The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

## 2 Incremental-Iterative Method

### 2.1 Assumptions

In applying the incremental-iterative method, the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, see 2.2.2 of this Appendix, which are considered to act independently.

According to the iterative procedure, the bending moment $M_i$ acting on the transverse section at each curvature value $\chi_i$ is obtained by summing the contribution given by the stress $\sigma$ acting on each element. The stress $\sigma$ corresponding to the element strain, $\varepsilon$ is to be obtained for each curvature increment from the non-linear load-end shortening curves $\sigma$-$\varepsilon$ of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in 2.3. The stress $\sigma$ is selected as the lowest among the values obtained from each of the considered load-end shortening curves $\sigma$-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value $\chi_F$, in $m^{-1}$, in hogging and sagging conditions, obtained from the following formula:

$$\chi_F = \pm\, 0.003 \frac{M_y}{EI_{y-net}}$$

where: $M_Y$ — lesser of the values $M_{Y1}$ and $M_{Y2}$, in kN·m.;

$M_{Y1} = 10^3\, R_{eH}\, ZB\text{-}net.$

$M_{Y2} = 10^3\, R_{eH}\, ZD\text{-}net.$

If the value $\chi_F$ is not sufficient to evaluate the peaks of the curve $M$-$\chi$, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

### 2.2 Procedure

2.2.1 General

The curve $M$-$\chi$ is to be obtained by means of an incremental-iterative approach, summarized in the flow chart in Figure 1.

In this procedure, the ultimate hull girder bending moment capacity, $M_U$ is defined as the peak value of the curve with vertical bending moment $M$ versus the curvature $\chi$ of the ship cross section as shown in Figure 1.

The curve is to be obtained through an incrementaliterative approach.
Each step of the incremental procedure is represented by the calculation of the bending moment $M_i$ which acts on the hull transverse section as the effect of an imposed curvature $\chi_i$.
For each step, the value $\chi_i$ is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step $\chi_{i-1}$. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.
This rotation increment induces axial strains $\varepsilon$ in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.
The stress $\sigma$ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve $\sigma$-$\varepsilon$ of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.
The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position due to the nonlinear σ-ε, relationship. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section.
Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section $M_i$ around the new position of the neutral axis, which corresponds to the curvature $\chi_i$ imposed in the step considered, is to be obtained by summing the contribution given by each element stress.
The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure 1):

Step 1: Divide the transverse section of hull into stiffened plate elements.

Step 2: Define stress-strain relationships for all elements as shown in Table 1.

Step 3: Initialise curvature $\chi_1$ and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1=\Delta\chi = 0.01\frac{R_{eH}}{E}\frac{1}{z_D - z_n}$$

where: $z_D$ — $Z$ coordinate, in m, of strength deck at side;
$z_n$ — Z coordinate, in m, of horizontal neutral axis of the hull transverse section with respect to the reference coordinate system defined in 7.2.1.2, Section 2 of this Chapter.

Step 4: Calculate for each element the corresponding strain, $\varepsilon_i=\chi(z_i-z_n)$ and the corresponding stress $\sigma_i$.

Step 5: Determine the neutral axis $z_{NA_cur}$ at each incremental step by establishing force equilibrium over the whole transverse section as:
$\Sigma A_{i\text{-}net}\,\sigma_i = \Sigma A_{j\text{-}net}\,\sigma_j$ ($i$-th element is under compression, $j$-th element under tension).

Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_{i-net}\left|\left(z_i - z_{NA_cur}\right)\right|.$$

Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M$-$\chi$ relationship is less than a negative fixed value, terminate the process and define the peak value $M_U$. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

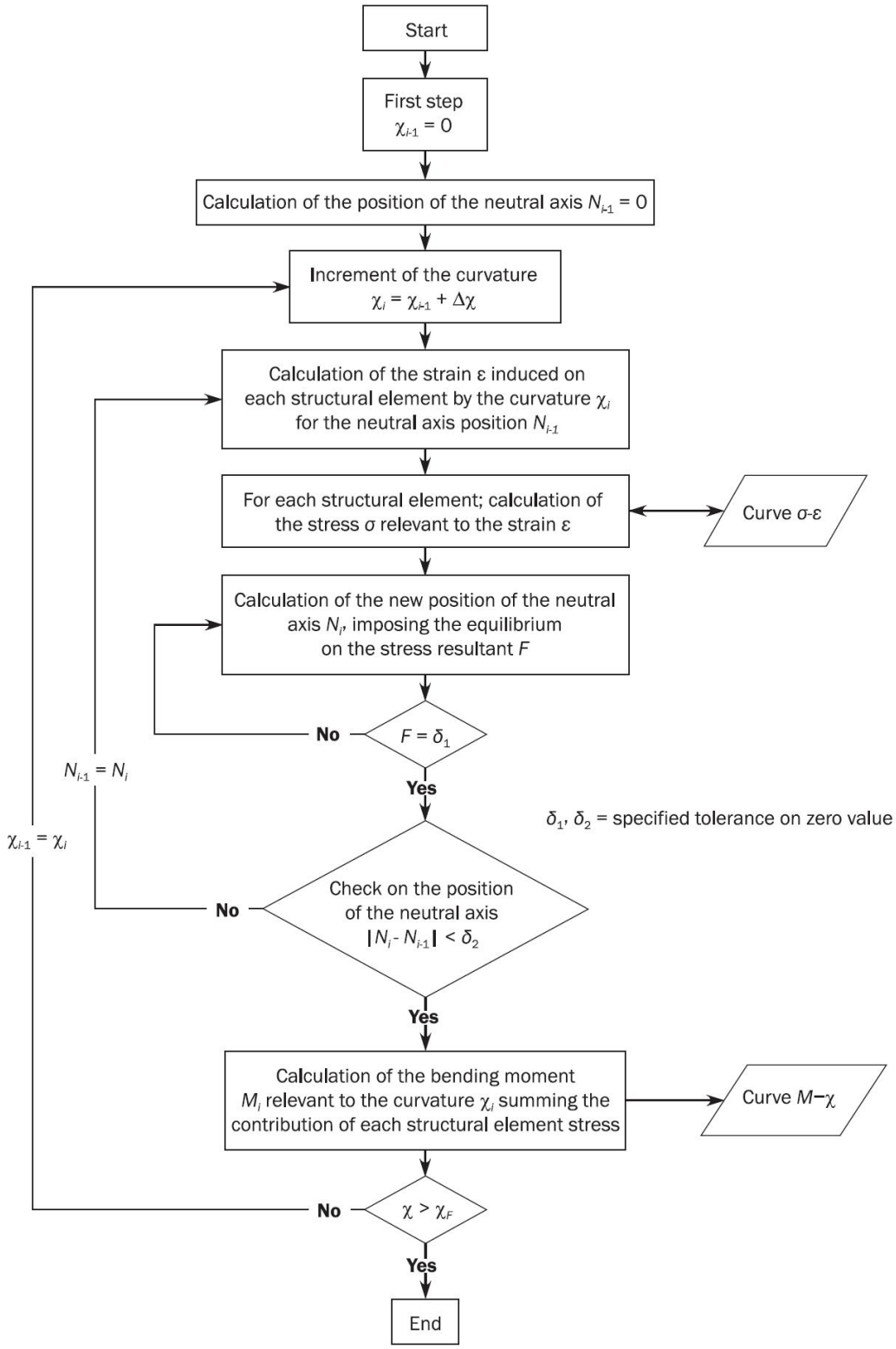



**Figure 1 Flow chart of the procedure for the evaluation of the curve *M-χ***

2.2.2 Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into a stiffened plate element, an

attached plate of a stiffener element or a hard corner element.
The plate panel is categorised into the following two kinds:

— longitudinally stiffened panel of which the longer side is in ship's longitudinal direction, and
— transversely stiffened panel of which the longer side is in the perpendicular direction to ship's longitudinal direction.

• Hard corner element:
Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.
The extent of a hard corner element from the point of intersection of the plates is to be taken equal to 20 $t_{net}$ on a transversely stiffened panel and to 0.5 $s$ on a longitudinally stiffened panel, see Figure 2.
where:

$t_{net}$ — net thickness of plate, in mm;
$s$ — spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.
• Stiffener element:
The stiffener constitutes a stiffener element together with the attached plate.
The attached plate width is in principle:

— equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
— equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

• Stiffened plate element:
The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

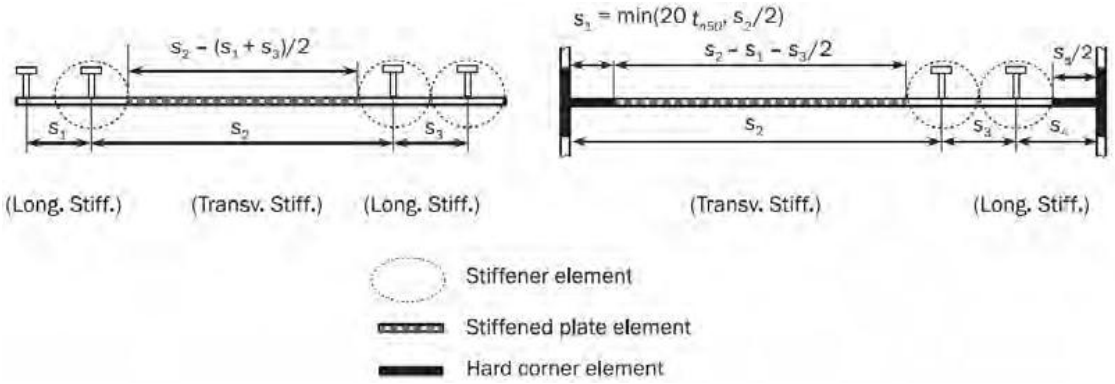



**Figure 2 Extension of the breadth of the attached plating and hard corner element**

The typical examples of modelling of hull girder section are illustrated in Figure 3.
Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch coaming.

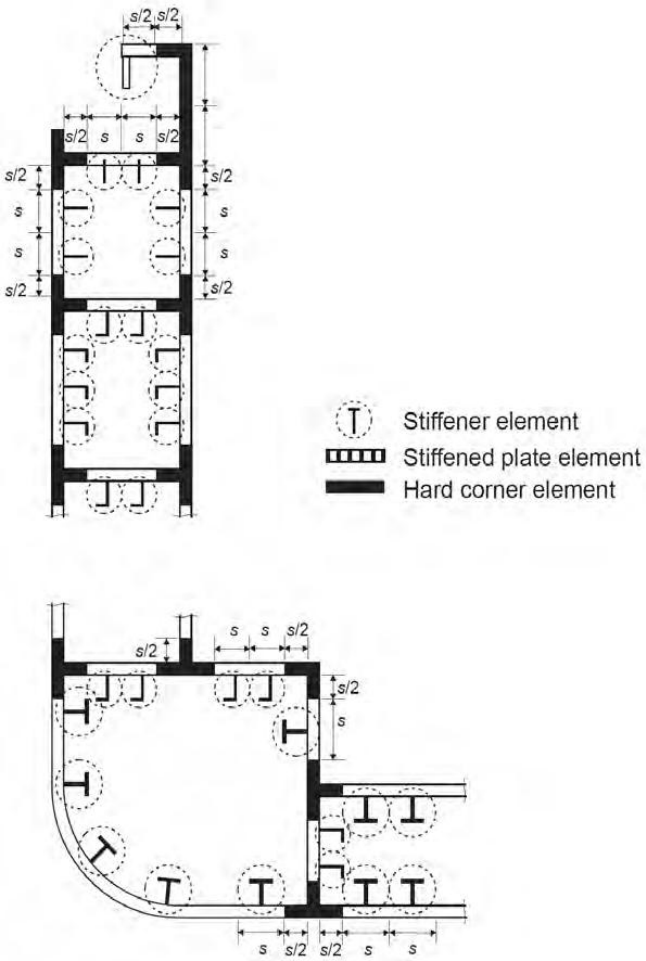



**Figure 3 Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section**

Notes:

(1) In case of the knuckle point as shown in Figure 4, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to 20 $t_{net}$ on transversely framed panels and to 0.5 $s$ on longitudinally framed panels from the knuckle point.

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non- continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with the requirements of Figure 2.2.4.7 of Section 2, Chapter 2 of this PART.

(4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation:

$$t_{net} = \frac{t_{1-net}s_1 + t_{2-net}s_2}{s} \qquad R_{eH_P} = \frac{R_{eH_P1}t_{1-net}s_1 + R_{eH_P2}t_{2-net}s_2}{t_{net}s}$$

where: $R_{eH_p1}$, $R_{eH_p2}$, $t_{1\text{-}net}$, $t_{2\text{-}net}$, $s_1$, $s_2$ and $s$ are shown in Figure 5.

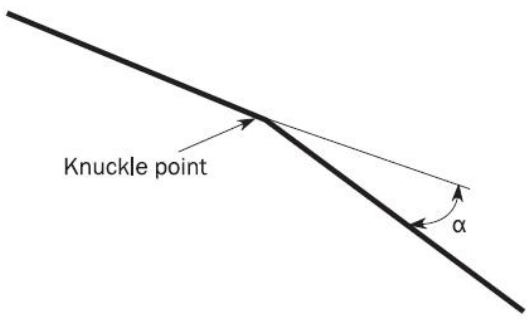



**Figure 4 Plating with knuckle point**

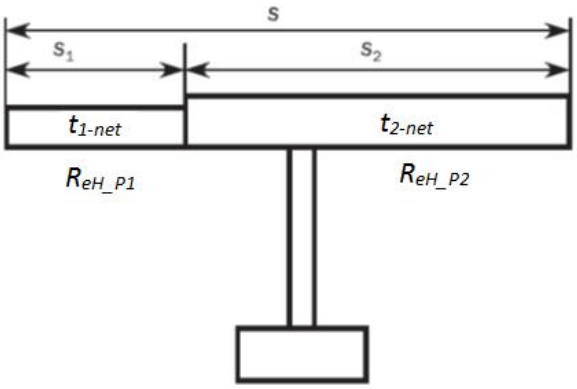



**Figure 5 Element with different thickness and yield strength**

## 2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with 2.3.2 to 2.3.7 of this Appendix, taking into account the non-continuous longitudinal stiffener.

In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength.
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

**Modes of failure of stiffened plate element and stiffener element Table 1**

| Element | Mode of failure | Curve $\sigma$-$\varepsilon$ defined in |
|---|---|---|
| Lengthened stiffened plate element or stiffener element | Elasto-plastic collapse | 2.3.2 of this Appendix |
| Shortened stiffener element | Beam column buckling | 2.3.3 of this Appendix |
| | Torsional buckling | 2.3.4 of this Appendix |
| | Web local buckling of flanged profiles | 2.3.5 of this Appendix |
| | Web local buckling of flat bars | 2.3.6 of this Appendix |
| Shortened stiffened plate element | Plate buckling | 2.3.7 of this Appendix |

2.3.2 Elasto-plastic collapse of structural elements (Hard corner element)

The equation describing the load-end shortening curve $\sigma$-$\varepsilon$ for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula.

$$\sigma = \Phi R_{eHA}$$

where: $R_{eHA}$ — equivalent minimum yield stress, in N/mm$^2$, of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eH_P}A_{p-net}+R_{eH_S}A_{s-net}}{A_{p-net}+A_{s-net}};$$

$\Phi$ — edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$;

$\Phi = \varepsilon$ for $-1 \le \varepsilon \le 1$;

$\Phi = 1$ for $\varepsilon > 1$;

$\varepsilon$ — relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y};$$

$\varepsilon_E$ — element strain;

$\varepsilon_Y$ — strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}.$$

2.3.3 Beam column buckling

The positive strain portion of the average stress – average strain curve $\sigma_{CR1}$ - $\varepsilon$ based on beam column buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-net} + A_{pE-net}}{A_{s-net} + A_{p-net}}$$

where: $\Phi$ — edge function, as defined in 2.3.2 of this Appendix;

$\sigma_{C1}$— critical stress, in N/mm$^2$, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon;$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon;$$

$R_{eHB}$ — equivalent minimum yield stress, in N/mm$^2$, of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eH_P}A_{pEI-net}\ell_{pE} + R_{eH_S}A_{s-net}\ell_{sE}}{A_{pEI-net}\ell_{pE} + A_{s-net}\ell_{sE}};$$

$A_{pEI\text{-}net}$ — effective area, in cm$^2$, equal to:

$$A_{pEI-net} = 10 b_{E1} t_{net};$$

$l_{pE}$ — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width $b_{E1}$ to the bottom of the attached plate;

$l_{sE}$ — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width $b_{E1}$ to the top of the stiffener;

$\varepsilon$ — relative strain, as defined in 2.3.2 of this Appendix;

$\sigma_{E1}$— Euler column buckling stress, in N/mm$^2$, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net}}{A_{E-net}\ell^2} 10^{-4};$$

$I_{E\text{-}net}$ — net moment of inertia of stiffeners, in cm$^4$, with attached plate of width $b_{E1}$;

$A_{E\text{-}net}$ — net area, in cm$^2$, of stiffeners with attached plating of width $b_{E1}$;

$b_{E1}$ — effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1.0;$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1.0;$$

where: $\beta_E = 10^3 \frac{s}{t_{n50}} \sqrt{\frac{\varepsilon R_{eHp}}{E}}$;

$A_{pE\text{-net}}$ — net area, in cm$^2$, of attached plating of width $b_E$, equal to:

$$A_{pE-net} = 10 b_E t_{net};$$

$b_E$ — effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1.25;$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1.25.$$

2.3.4 Torsional buckling

The load-end shortening curve $\sigma_{CR2}$-$\varepsilon$ for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net}\sigma_{C2} + A_{p-net}\sigma_{Cp}}{A_{s-net} + A_{p-net}}$$

where: $\Phi$ — edge function, as defined in 2.3.2 of this Appendix;

$\sigma_{C2}$ — critical stress, in N/mm$^2$, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH_S}}{2}\varepsilon;$$

$$\sigma_{C2} = R_{eH_S}\left(1 - \frac{R_{eH_S}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH_S}}{2}\varepsilon;$$

$\varepsilon$— relative strain, as defined in 2.3.2 of this Appendix;

$\sigma_{E2}$— Euler column buckling stress, in N/mm$^2$, taken as $\sigma_{ET}$ defined in 4.4.4 of Appendix 4 of this Chapter;

$\sigma_{CP}$— buckling stress of the attached plating, in N/mm$^2$, equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) R_{eH_P} \qquad \text{for } \beta_E > 1.25$$

$$\sigma_{CP} = R_{eH_P} \qquad \text{for } \beta_E \le 1.25$$

$\beta_E$— coefficient, as defined in 2.3.3 of this Appendix.

2.3.5 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve $\sigma_{CR3}$ - $\varepsilon$ for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{net} R_{eH_P} + \left(h_{we} t_{w-net} + b_f t_{f-net}\right) R_{eH_S}}{10^3 s t_{net} + h_w t_{w-net} + b_f t_{f-net}}$$

where: $\Phi$ — edge function, as defined in 2.3.2 of this Appendix;

$b_E$ — effective width, in m, of the attached plating, as defined in 2.3.3 of this Appendix;

$h_{we}$ — effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \qquad \text{for } \beta_w \ge 1.25;$$

$$h_{we} = h_w \qquad \text{for } \beta_w < 1.25;$$

$\beta_w$ — $\beta_w = \frac{h_w}{t_{w-net}} \sqrt{\frac{\varepsilon R_{eH_S}}{E}}$;

$\varepsilon$— relative strain, as defined in 2.3.2 of this Appendix.

2.3.6 Web local buckling of stiffeners made of flat bars

The load-end shortening curve $\sigma_{CR4}$-$\varepsilon$ for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \frac{A_{p-net}\sigma_{CP} + A_{s-net}\sigma_{C4}}{A_{p-net} + A_{s-net}}$$

where: $\Phi$ — edge function, as defined in 2.3.2 of this Appendix;

$\sigma_{CP}$ — buckling stress of the attached plating, in N/mm$^2$, as defined in 2.3.4 of this Appendix;

$\sigma_{C4}$ — critical stress, in N/mm$^2$, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \le \frac{R_{eH_S}}{2}\varepsilon;$$

$$\sigma_{C4} = R_{eH_S}\left(1 - \frac{R_{eH_S}\varepsilon}{4\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{R_{eH_S}}{2}\varepsilon;$$

$\sigma_{E4}$ — local Euler buckling stress, in N/mm$^2$, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_{w-net}}{h_w}\right)^2;$$

$\varepsilon$— relative strain, as defined in 2.3.2 of this Appendix.

2.3.7 Plate buckling

The load-end shortening curve $\sigma_{CR5}$-$\varepsilon$ for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = min\begin{Bmatrix} R_{eH_P}\Phi \\ \Phi R_{eH_P}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{Bmatrix}$$

where: $\Phi$ — edge function, as defined in 2.3.2 of this Appendix;

$\beta_E$ — coefficient as defined in 2.3.3 of this Appendix;

$s$ — plate breadth, in m, taken as the spacing between the stiffeners;

$l$— longer side of the plate, in m.

## 3 Alternative Methods

### 3.1 General

3.1.1 Application of alternative methods is to be agreed prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

3.1.2 The bending moment-curvature relationship, $M$-$\chi$, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

(a) non-linear geometrical behavior;
(b) inelastic material behavior;
(c) geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners);
(d) simultaneously acting loads:
- bi-axial compression;
- bi-axial tension;
- shear and lateral pressure;

(e) boundary conditions;
(f) interactions between buckling modes;
(g) interactions between structural elements such as plates, stiffeners, girders, etc.;
(h) post-buckling capacity;
(i) overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners, etc. (double bottom effects or similar).

**3.2 Non-linear finite element analysis**

3.2.1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in 3.1.2.

3.2.2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

# CHAPTER 8 BULK CARRIERS

## Section 1 GENERAL PROVISIONS

### 8.1.1 Application

8.1.1.1 Bulk carriers are ships provided with single deck, double bottom, topside tank and hopper tank, and intended primarily to carry dry cargo in bulk, not including ore carriers.

8.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

8.1.1.3 Double side skin bulk carriers referred to in this Chapter are bulk carriers of which all cargo holds are bounded by double side skin construction of not less than 1000 mm breadth between the inner shell and the outer shell

### 8.1.2 Plans and documents

8.1.2.1 In addition to the plans and documents specified in Section 1, Chapter 2 of this PART, the following are to be submitted for information:

(1) the maximum pressure head in service on tanks and details of any double bottom tanks interconnected with hopper tanks and topside tanks;

(2) details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds.

### 8.1.3 Direct strength calculation and fatigue strength assessment for hull structure

8.1.3.1 For bulk carriers of 150 m or over in length, direct calculation is to be carried out for the strength of primary structural members (both longitudinal and transverse) within cargo area in accordance with the requirements of Appendix 1 of this Chapter.

8.1.3.2 For bulk carriers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of hopper tanks or inner shell to inner bottoms;

(4) connections of inner bottoms to lower stool side plates;

(5) connections of corrugated transverse bulkheads to lower stool top plates;

(6) connections of corrugated transverse bulkheads to upper stool sloping plates;

(7) connections of frames to top side tanks and hopper tanks of single hull bulk carriers.

### 8.1.4 Protection of cargo holds from loading/discharge equipment

8.1.4.1 In bulk carriers of 150 m in load line length $L_L$ and upwards, carrying solid bulk cargoes having a density of 1,000 kg/m$^3$ and above, wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of topside tank plates), hatch end beams or upper portion of hatch coamings.

## Section 2 BOTTOM STRUCTURES

### 8.2.1 General requirements

8.2.1.1 For bulk carriers strengthened for heavy cargoes, the bottom structures are to comply with the provisions in Section 22, Chapter 2 of this PART.

8.2.1.2 Where the double bottom tanks are interconnected with hopper side tanks, the scantlings are to satisfy the requirements of Section 13, Chapter 2 of this PART for deep tanks.

8.2.1.3 For bulk carries of 150 m and over in length, the thickness of solid floors are determined by direction calculations, but the minimum thickness is not be less than that obtained from the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 3, \quad 12\right) \qquad \text{mm}$$

where: $L$—length of ship, in m, to be taken not greater than 300 m in calculation.

8.2.1.4 For bulk carries of 150 m and over in length, the thickness of watertight solid floors is also to

comply with the requirements for deep tanks in Section 13, Chapter 2, in addition to complying with the requirements of 8.2.1.3.

8.2.1.5 For longitudinally framed double bottom, where it is verified by direct calculation, a maximum of 1.5 times frame spacing may be accepted for the spacing between bottom and inner bottom stiffening members within the duct keel.

8.2.1.6 For bulk carriers of less than 150 m in length, strengthened for heavy cargoes with specified or alternate holds empty, the bottom structures are to comply with the requirements of this Section and in addition, the direct calculation is to be carried out for the strength of primary members of double bottom (both longitudinal and transverse) in accordance with the requirements of Appendix 1 of this Chapter.

# Section 3 SIDE FRAMING

### 8.3.1 Application

8.3.1.1 This Section applies to side structures of cargo holds bounded by the side shell only of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk.

### 8.3.2 Side shell plating

8.3.2.1 The thickness of the side shell plating is to be determined according to the requirements in Chapter 2 of this PART. The thickness $t$ of the shell plating between hopper and topside tanks within the cargo area is not to be less than that obtained from the following formula:

$$t = \sqrt{L} \quad \text{mm}$$

where: $L$ — length of ship, in m.

### 8.3.3 Main Frames

8.3.3.1 For bulk carriers of 190 m and over in length, the main frames within the cargo area are to be integral with their upper and lower brackets and symmetrical in their transverse section.

8.3.3.2 In bulk carriers less than 190 m in length, mild steel main frames within the cargo area may be fitted with separate brackets and asymmetric in their transverse section.

8.3.3.3 The minimum web thickness of main frames is to be obtained from the following formula:

$$t = 7.0 + 0.03L \quad \text{mm}$$

where: $L$ — length of ship, in m, need not be taken greater than 200 m.

8.3.3.4 The section modulus $W$ of the main frames in holds is not to be less than that obtained from the following formula:

$$W = 5.8\, sh_1 l^2 K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;

$K$ — material factor;

$h_1$ — vertical distance, in m, measured between the midpoint of the span of frames and a point situated at $0.01L + 0.8$ above the load waterline, see Figure 8.3.3.4, where: $L$ — the length of ship, in m;

$l$ — span of frame, in m, i.e. the distance measured between the intersection of sloping plating with the side shell; for $l < 0.25D$, to be taken as $0.25D$ ($D$ being moulded depth, in m).

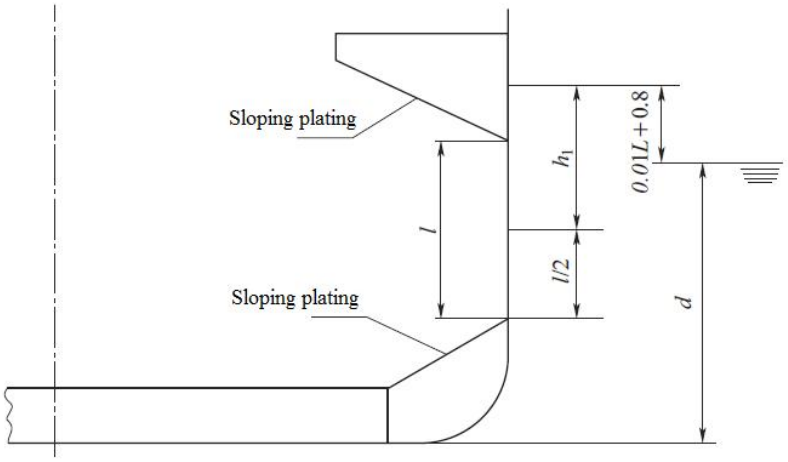



**Figure 8.3.3.4**

8.3.3.5 The web depth to thickness ratio of main frames is not to exceed the following values:

$60\sqrt{K}$ for symmetrically flanged frames

$50\sqrt{K}$ for unsymmetrically flanged frames

where: $K$ — material factor.

8.3.3.6 The maximum breadth of the frame flange outstand is not to exceed $10\sqrt{K}$ times the thickness of the flange.

8.3.3.7 The frame flange is to be radiused at the connection with the end brackets (see Figure 8.3.3.7), with the radius of curvature being not less than that obtained by the following formula:

$$r = \frac{0.4b_f^2}{t_f} \quad \text{mm}$$

where: $b_f$ — face plate width of lower or upper bracket, in mm;

$t_f$ — face plate thickness of lower or upper bracket, in mm.

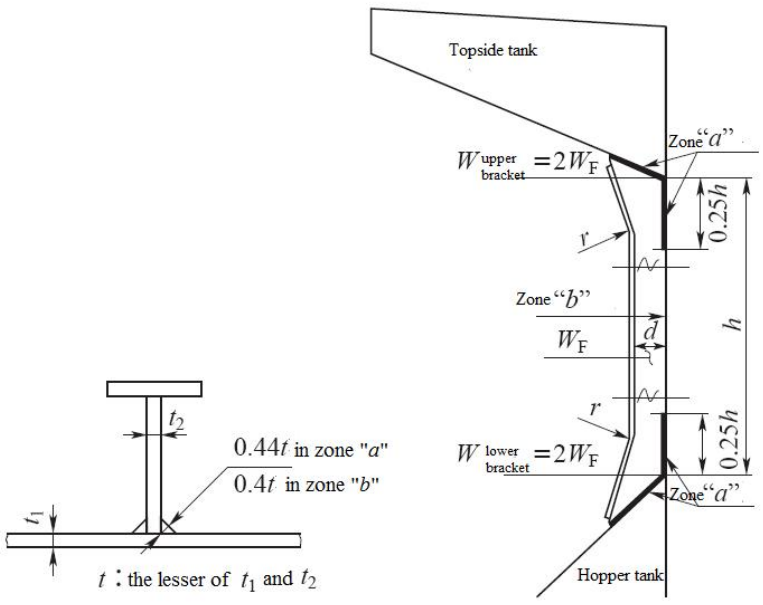



**Figure 8.3.3.7**

### 8.3.4 Lower and upper brackets of main frames

8.3.4.1 The thickness of the lower brackets is not to be less than that of the frame webs, nor to be less than that derived from 8.3.3.3 of this Section plus 2 mm.

8.3.4.2 The thickness of the upper brackets is not to be less than that of the frame webs.

8.3.4.3 The dimensions of the lower and upper brackets are not to be less than those shown in Figure 8.3.4.3.

8.3.4.4 The section modulus of the frame and the bracket or integral bracket, at the locations shown in Figure 8.3.3.7, is not to be less than twice the value obtained as per 8.3.3.4 of this Section.
8.3.4.5 The structural continuity of the upper and lower end connections of the frames is to be ensured by connecting brackets, as shown in Figure 8.3.4.5, within topside and hopper tanks. The brackets are in general to be stiffened against buckling in accordance with Figure 8.3.4.5.

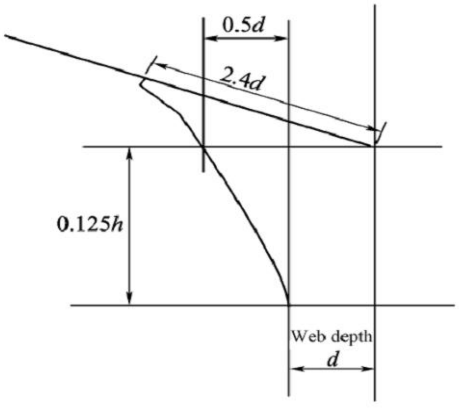



Figure 8.3.4.3

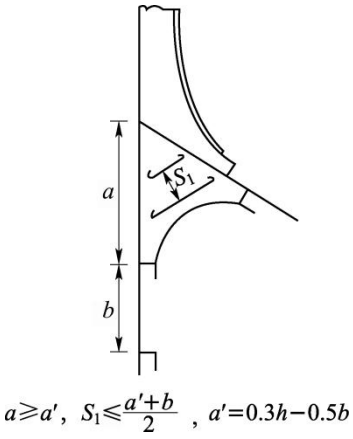



Figure 8.3.4.5

8.3.4.6 Upper and lower brackets are to be arranged at their ends with soft toes as shown in Figure 1.2.7.6 of Section 2, Chapter 1 of this PART.
8.3.4.7 The section moduli of the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals which support the connecting brackets in 8.3.4.5 are to be determined with the span taken between transverses. When the arrangement of the upper and lower brackets of the frames and the connecting brackets is different from this Section, the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals are to effectively support the connecting brackets.

### 8.3.5 Strengthening of side structures in the foremost hold

8.3.5.1 The minimum web thickness of main frames is to be 1.15 times that required in 8.3.3.3 of this Section.
8.3.5.2 The scantlings of the main frames immediately adjacent to the collision bulkhead are to be properly increased in order to prevent deformation of the shell plating. As an alternative, side stingers or perforated platforms in the forepeak may be extended to the foremost frame of the foremost hold. The extension is to be provided with an adequate shear-resistant area for connection with the frame.
8.3.5.3 Where main frames of the foremost hold are asymmetrical in their transverse section, tripping brackets are to be fitted close to the mid-span of every second frame, as shown in Figure 8.3.5.3.

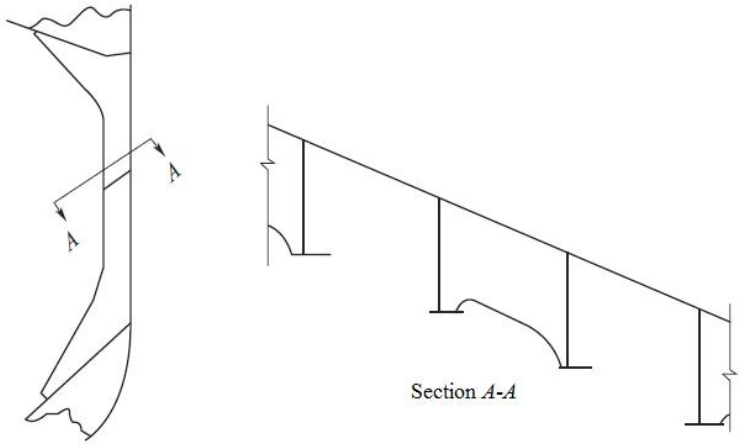



Figure 8.3.5.3

### 8.3.6 Weld connections of frames and brackets to side shell and sloping plating

8.3.6.1 Double continuous welding is to be adopted for the fillet-weld connections of frames and brackets to side shell, topside and hopper tank sloping plating and web to face plates. For this purpose, the weld

throat is to be (see Figure 8.3.3.7):

0.44 $t$ in zone "a"

0.4 $t$ in zone "b"

where: $t$ — the thinner of the two connected members, in mm.

8.3.6.2 Where the hull form is such that an effective fillet weld cannot be made, edge preparation of the web of the frame and bracket may be required, in order to ensure the required efficiency of the weld connection.

# Section 4 WATERTIGHT BULKHEADS

### 8.4.1 General requirements

8.4.1.1 Watertight bulkheads are to comply with the requirements of Section 12, Chapter 2 of this PART. The transverse bulkheads forming boundaries of ballast holds are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.

8.4.1.2 Stools, if fitted at the top and bottom of the corrugated watertight bulkhead, are to comply with the following requirements:

(1) The sloping plating of lower stools is to be fitted on solid floors. The thickness of the sloping plating is not to be less than that of the bulkhead plating required in Section 12, Chapter 2 of this PART and in addition, is not to be less than that required in 8.5.2.1 of this Chapter for the sloping plating of hopper tanks.

(2) Where stiffeners are fitted on the sloping plating of lower stools, their section modulus is not to be less than that required in 8.5.3.1 of this Chapter for the longitudinals on the sloping plating of hopper tanks.

(3) Diaphragms are to be fitted in lower stools in way of bottom girders, having the same thickness as that of the inner bottom longitudinal girders.

(4) The upper stool is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to twice the depth of corrugations, measured from the deck level and at hatch side girder. The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than twice the depth of corrugations.

(5) Stool structures situated in liquid tanks are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks.

# Section 5 HOPPER TANKS

### 8.5.1 General requirements

8.5.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the hopper tanks in way of the watertight bulkheads in holds. Otherwise wash bulkheads are to be fitted.

8.5.1.2 Consideration is to be given to the structural continuity of both ends of hopper tanks.

8.5.1.3 For the calculation of design head $h$ of hopper tank structural members, the tank top is to be measured from the highest point of the topside tank where hopper tanks are interconnected with topside tanks, or the highest point of the ballast tank within double side skin where hopper tanks are interconnected with such ballast tanks.

8.5.1.4 The requirements of this Section apply to hopper tanks framed longitudinally.

### 8.5.2 Sloping plating

8.5.2.1 The thickness of the sloping plating is not to be less than that of inner bottom plating as required in Section 6, Chapter 2 of this PART. For ships strengthened for heavy cargoes, the sloping plating is to be increased in thickness in accordance with the requirements of 2.22.3.4 of this PART, but this increase may be gradually tapered from the intersection of sloping plating and inner bottom plating to nil at the top corner of the tank. Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the thickness of the sloping plating is not to be less than that required in Section 13, Chapter 2 of this PART for deep tanks.

8.5.2.2 Where the hopper tanks are fitted with watertight side bulkheads, the thickness $t$ of the side bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

$K$ — material factor.

### 8.5.3 Longitudinals

8.5.3.1 The section modulus $W$ of the sloping plating longitudinals is not to be less than that of the inner bottom longitudinals as required in Section 6, Chapter 2 of this PART.

For ships strengthened for heavy cargoes, the section modulus is nor to be less than that obtained from the following formula:

$$W = 8.5Hsl^2K/\gamma \quad \text{cm}^3$$

where: $\gamma$ — see Section 22, Chapter 2 of this PART;

$H$ — vertical distance, in m, measured from longitudinal to the lower edge of the sloping plating of topside tanks; where no topside tank is provided, measured from longitudinal to upper deck;

$s$ — spacing of longitudinals, in m;

$l$ — span of longitudinal, in m;

$K$ — material factor.

Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the section modulus $W$ of the sloping plating longitudinals is not to be less than:

$$W = 9shl^2K \quad \text{cm}^3$$

where: $s$, $l$, $K$— same as defined above;

$h$ — vertical distance, in m, measured from the longitudinal to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater.

8.5.3.2 The section modulus $W$ of side and bilge longitudinals in hopper tanks is not to be less than that required in Section 7, Chapter 2 of this PART.

8.5.3.3 The section modulus $W$ of bottom longitudinals in hopper tanks is not to be less than that required in Section 6, Chapter 2 of this PART.

### 8.5.4 Transverse supporting structural members

8.5.4.1 Transverse structural members supporting the longitudinals of the hopper tanks are to be fitted in way of the floors within holds.

8.5.4.2 The section modulus $W$ and the section moment of inertia $I$ of bottom transverses and side shell transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $S$ — spacing of bottom or side shell transverses, in m;

$l$ — span of bottom or side shell transverse, in m;

$h$ — vertical distance, in m, from the mid-point of span to the upper deck at side;

$K$ — material factor.

8.5.4.3 The section modulus $W$ and the section moment of inertial $I$ of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $S$ — spacing of transverses, in m;

$l$ — span of transverse, in m;

$h$ — vertical distance, in m, measured from the mid-point of span to the tank top of or half of the vertical distance to the top of the overflow, whichever is the greater;

$K$ — material factor.

For ships strengthened for heavy cargoes, the section modulus $W$ and the section moment of inertial $I$ of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 6.6HSl^2K/\gamma \quad \text{cm}^3$$

$$I = 1.8Wl/K \quad \text{cm}^4$$

where: $\gamma$ — see Section 22, Chapter 2 of this PART;

$H$ — vertical distance, in m, measured from the mid-point of span to the lower edge of the sloping plating of the topside tank;

$S$ — spacing of transverses, in m;

$l$ — span of transverse, in m;

$K$ — material factor.

8.5.4.4 Bottom transverses, side shell transverses and sloping plating transverses are to be effectively connected one another. Longitudinals are to be continuous through the bottom and side shell transverses

and the sloping plating transverses, and are to be welded to their web plates. The web depth of primary supporting members is not to be less than 2.5 times the depth of the slot for the passage of longitudinals, and the web is to be suitably fitted with stiffeners between sloping plating longitudinals and bottom longitudinals or side longitudinals in compliance with the same requirements in 2.6.11.2 of Section 6, Chapter 2 of this PART. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

8.5.4.5 Where non-watertight transverse webs are provided in lieu of the above-mentioned bottom transverses, side shell transverses and slopping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 8.5.6.

8.5.4.6 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted above the hopper tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the hopper tank, and the length of the brackets, measured along the sloping plating and the side shell, is not to be less than that of the free edge of the lower brackets of the hold main frames. These brackets are to be welded to the adjacent longitudinals. Buckling-restrained stiffeners are to be fitted to the brackets. The direction of stiffeners is shown in Figure 8.3.4.5 of this Chapter and their sectional scantlings are to be the same as that of the stiffeners on bottom transverses.

### 8.5.5 Watertight bulkheads

8.5.5.1 The thickness $t$ of watertight bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

$K$ — material factor.

8.5.5.2 The section modulus $W$ of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 8.2shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$h$ — vertical distance, in m, measured from the mid-point of span of the stiffeners to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

$l$ — span of stiffener, in m;

$K$ — material factor.

Stiffeners are to be bracketed at both ends.

### 8.5.6 Non-watertight bulkheads and wash bulkheads

8.5.6.1 The plating thickness $t$ of non-watertight or wash bulkheads is not to be less than that obtained from the following formula and not to be less than 8 mm:

$$t = 12s \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m.

8.5.6.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 8.5.5.2 of this Section. Stiffeners are to be bracketed at both ends.

## Section 6 TOPSIDE TANKS

### 8.6.1 General requirements

8.6.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the topside tanks in way of the watertight bulkheads in holds. Otherwise, wash bulkheads are to be fitted.

8.6.1.2 Consideration is to be given to the structural continuity of both ends of topside tanks.

### 8.6.2 Sloping plating and vertical side plating

8.6.2.1 The thickness $t$ of the sloping plating is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

$$t = 12s/\sqrt{K} \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

$h_1$ — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

The thickness of the lowest strake is to be increased by 1 mm above that obtained from the above formula.

8.6.2.2 The thickness of the vertical side plating fitted in line with hatch side coamings and of the top strake of the topside tank sloping plating is not to be less than 60% of that of the deck plate outside the line of openings, nor to be less than 18$s$ ($s$ being the spacing of longitudinals, in m). Brackets, spaced not more than 2 frame spaces apart, are to be fitted at the vertical side plating, and extended to deck and sloping plating longitudinals and welded to them.

### 8.6.3 Longitudinals

8.6.3.1 The section modulus $W$ of deck, sloping plating and side longitudinals are not to be less than that of the following formula:

$$W = 10shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$l$ — span of longitudinal, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the longitudinal to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;

$h_1$ — vertical distance, in m, measured from the longitudinal to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the longitudinal to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

8.6.3.2 The scantlings of deck and side longitudinals are also to comply with the relevant requirements of Chapter 2 of this PART.

### 8.6.4 Transverse supporting structural members

8.6.4.1 The section modulus $W$ and the section moment of inertia $I$ of the deck, sloping plating and side shell transverses supporting the longitudinals are not to be less than those obtained from the following formulae:

$$W = 7.5Shl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: $S$ — spacing of deck or side shell transverses, in m;

$l$ — span of deck or side shell transverse, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;

$h_1$ — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

8.6.4.2 The scantlings of deck or side shell transverses are not to be less than as required in Chapter 2 of this PART. Their web depth is not to be less than twice the depth of the slot for the passage of longitudinals. The web thickness is not to be less than 1% of its depth plus 4 mm.

8.6.4.3 The deck, sloping plating and side shell transverses are to be connected one another by brackets.

8.6.4.4 The longitudinals are to be continuous through the deck, sloping plating and side shell transverses, and are to be welded to their web plates. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

8.6.4.5 Primary transverse members supporting the longitudinals in topside tanks are, in general, to be spaced not more than 3.6 m apart for ships equal to or less than 100 m in length, and not more than $0.006L + 3.0$ m apart for ships more than 100 m in length. Larger spacing may be accepted where the evaluation is carried out by means of direct strength calculation in accordance with the requirements of Appendix 1 of this Chapter.

8.6.4.6 Where non-watertight transverse webs are provided in lieu of the above-mentioned deck transverses, side shell transverses and slopping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 8.6.7.

8.6.4.7 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted below the topside tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the topside tank, and these brackets are to be extended and welded to the adjacent longitudinals along the side shell and sloping plating. The brackets are to be in line with the upper brackets of the hold main frames.

8.6.4.8 Where a rounded gunwale is adopted, a bracket is to be fitted in way of the rounded gunwale approximately halfway between transverses, extending and welded to the adjacent deck and shell longitudinals.

8.6.4.9 Transverse supporting members are to be arranged in topside tanks in line with hatch end coamings.

### 8.6.5 Shell framing

8.6.5.1 Where the side shell is framed transversely, the section modulus $W$ of the frames is not to be less than that obtained from the following formula:

$$W = 10shl^2K \qquad \text{cm}^3$$

where: $s$ — spacing of frames, in m;

$l$ — span of frame, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

$h_1$ — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

Frames are also to comply with the requirements of 2.13.6.1 of this PART.

8.6.5.2 Bracket are to be fitted at both ends of frames, extended and welded to the adjacent deck and sloping plating longitudinals. The thickness of brackets is to be the same as that of the upper brackets of hold main frames.

### 8.6.6 Watertight bulkheads

8.6.6.1 The thickness $t$ of the watertight bulkheads is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$t = 4s\sqrt{hK} + 2.5 \qquad \text{mm}$$

$$t = 12s/\sqrt{K} \qquad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the lower edge of strake to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

$h_1$ — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

The thickness of the lowest strake is to be increased by 1 mm above that derived from above.

8.6.6.2 The section modulus $W$ of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 10shl^2K \qquad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;

$l$ — span of stiffener, in m;

$K$ — material factor;

$h$ = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

$h_1$ — the vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;

$b_1$ — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta$ = 30°.

The stiffeners are to be bracketed at both ends.

**8.6.7 Non-watertight and wash bulkheads**

8.6.7.1 The plating thickness $t$ of non-watertight or wash bulkheads is to be in compliance with 8.5.6.1 of this Chapter.

8.6.7.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 8.6.6.2 of this Section. The stiffeners are to be bracketed at both ends.

# Section 7 ADDITIONAL REQUIREMENTS FOR LOADING MANUALS AND LOADING INSTRUMENTS

**8.7.1 General requirements**

8.7.1.1 This Section applies to bulk carriers, ore carriers and combination carriers of 150 m and over in length.

8.7.1.2 Hold mass curves are calculated and drawn in accordance with Appendix 2 of this Chapter.

**8.7.2 Loading manuals**

8.7.2.1 The loading manual is to describe:

(1) the loading condition on which the design of the ship has been based, including still water bending moments and shear forces and where applicable, the results of the calculations of torsional loads;

(2) permissible limits of still water bending moments and shear forces;

(3) the cargo hold(s) or combination of cargo holds that may be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual;

(4) maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position;

(5) maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught is to be calculated by averaging the draught at the two mid-hold positions;

(6) maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes;

(7) maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual;

(8) the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the achievable rates of change of ballast.

8.7.2.2 Conditions of approval of loading manuals

In addition to the requirements given in 2.2.8.11 of this PART, the following conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

(1) Alternate light and heavy cargo loading conditions at maximum draught, where applicable;

(2) Homogeneous light and heavy cargo loading conditions at maximum draught;

(3) Ballast conditions. For bulk carriers having ballast holds adjacent to topside wing, hopper and double bottom tanks, it is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty;

(4) Short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers, where applicable;

(5) Multiple port loading/unloading conditions, where applicable;

(6) Deck cargo conditions, where applicable;

(7) Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The

typical loading/unloading sequences are to be developed not to exceed applicable strength limitations. These sequences are to be developed paying due attention to loading/unloading rate and deballasting capacity. Table 8.7.2.2 shows an example of the Sheet of Loading Sequences for guidance;
(8) Typical sequences for exchange of ballast water at sea, where applicable.

### 8.7.3 Loading instrument

8.7.3.1 A loading instrument with the display function is an approved digital system as defined in 2.2.8.4 of this PART. In addition to the requirements in 2.2.8.4 of this PART, it is to ascertain as appropriate that:
(1) the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position;
(2) the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds.
8.7.3.2 Conditions of approval of loading instruments
The loading instrument is subject to approval. In addition to the requirements given in 2.2.8.12 of this PART, the approval is to include as applicable:
(1) acceptance of hull girder bending moment limits for all read-out points;
(2) acceptance of hull girder shear force limits for all read-out points;
(3) acceptance of limits for mass of cargo and double bottom contents of each hold as a function of draught;
(4) acceptance of limits for mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

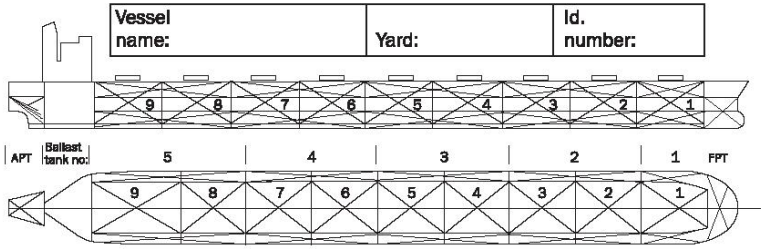
### 8.7.4 Guidance for loading/unloading sequences

8.7.4.1 Where a typical loading/unloading sequences manual is prepared, due attention is to be given to the loading/unloading rate, ballasting/deballasting capacity and applicable strength limitations.
8.7.4.2 The typical loading/unloading sequence is to be prepared and submitted for approval by shipyard.
8.7.4.3 The relevant contents of typical loading/unloading sequences are to include:
(1) alternate light and heavy cargo loading conditions;
(2) homogeneous light and heavy cargo loading conditions;
(3) short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers;
(4) multi-port loading/unloading conditions;
(5) deck cargo condition;
(6) alt-block loading condition.
8.7.4.4 The loading/unloading sequences may be for a specific port or a typical sequence.
8.7.4.5 The loading/unloading sequences of the selected loading condition are to be compiled one step by one step from commencement of cargo loading to reaching full deadweight capacity. A step is finished when the loading equipment is moved to another cargo hold. File is to be submitted for each step. In addition to the longitudinal strength, the local strength of each cargo hold is to be taken into consideration.
8.7.4.6 Each loading condition is to include the summary of all steps. It is to focus on the key information of each step, such as:
(1) the capacity of cargoes in each cargo hold for different steps;
(2) the volume of discharged ballast water for each ballast tank in different steps;
(3) the maximum still water bending moment and shear force when each step is finished;
(4) the trim and draught of ship when each step is finished.

## Typical Sheet of Loading Sequences for Guidance

**Table 8.7.2.2**

| Vessel name: | Yard: | Id. number: |
|---|---|---|




| | | |
|---|---|---|
| Port (specific or typical): | Condition at commencement of loading/discharging: | |
| Total mass of cargo to be loaded/discharged: | Condition at end of loading/discharging: | |
| Dock water density (t/m³): | Maximum loading/discharging rate: | Average loading/discharging rate: |
| Number of loaders/dischargers: | Maximum ballasting/deballasting rate: | Average ballasting/deballasting rate: |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Volume of Hold, Vh (m³) | | | | | | | | | |
| Height of hold, h (m) | | | | | | | | | |

Note: During each pour it it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow fo ballasting/deballasting in order to keep actual values within limits.

| Hold content at commencement of loading/discharging | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cargo mass | | | | | | | | | |
| Density (t/m³) | | | | | | | | | |
| Grade | | | | | | | | | |

| Ballast content at commencement of loading/discharging | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Wings or peaks | APT | Ball. no. 5 | Ball. no. 4 | Hold. no. 6 | Ball. no. 3 | Hold. no. 4 | Ball. no. 2 | Ball. no. 1 | FPT |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |

| Commencement of loading/discharging (sea) | | | | |
|---|---|---|---|---|
| T aft (m) | T rim (m) | T fwd (m) | Maximum | |
| | | | S.F. (%) | B.M. (%) |
| | | | | |

| CARGO OPERATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pour no. /grade | Hold 9 | Hold 8 | Hold 7 | Hold 6 | Hold 5 | Hold 4 | Hold 3 | Hold 2 | Hold 1 |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| | | | | | | | | | |
| Draft Survey (for loading): | Total cargo onboard (t): | | | | Remaining cargo to be loaded (t): | | | | |
| n-1 | | | | | | | | | |
| n | | | | | | | | | |

| BALLAST OPERATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Upper Lower/Peaks | APT | Ballast tank no. 5 | Ballast tank no. 4 | No.5 Ballast hold | Ballast tank no.3 | No.4 Ballast hold | Balalst tank no. 2 | Ballast tank no.1 | FPT |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Total amount of bunkers onboard (t): | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |

| Values at end of pour (from harbour to sea) | | | | |
|---|---|---|---|---|
| T aft (m) | T rim (m) | T fwd (m) | Maximum | |
| | | | S.F. (%) | B.M. (%) |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| Hold content at end of loading/discharging | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cargo mass: | | | | | | | | | |
| Total mass loaded/discharge (t): | | | | | | | | | |

| Ballast content at end of loading/discharging | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Wings or peaks | APT | Ball. no. 5 | Ball. no. 4 | No. 6 hold | Ball. no. 3 | No. 4 hold | Ball. no. 2 | Ball. no. 1 | FPT |
| Upper | | | | | | | | | |
| Lower/Peaks | | | | | | | | | |

| Values at end of loading/discharging (sea) | | | | |
|---|---|---|---|---|
| T aft (m) | T rim (m) | T fwd (m) | Maximum | |
| | | | S.F. (%) | B.M. (%) |
| | | | | |

| Maximum occuring values among all conditions above | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Net load on Double Bottom: | | | | | | | | | tons/m² |
| Net load in two adjacent holds: | | | | | | | | | tons |

Net load on double bottom = (Mh/V) h-T (t/m²)
- where: Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by:

Place, date, stamp and sign

# Section 8 EVALUATION OF SCANTLINGS OF HATCH COVERS OF CARGO HOLDS

**8.8.1 General requirements**

8.8.1.1 This Section applies to bulk carriers, ore carriers and combination carriers. The hatch covers of cargo holds are to comply with the relevant requirements of Section 20, Chapter 2 of this PART.

# Section 9 DOUBLE SIDE STRUCTURE

**8.9.1 General requirements**

8.9.1.1 This Section applies to the double side skin construction within the cargo area of bulk carriers.

8.9.1.2 Manholes are to be provided in transverse webs and horizontal girders. The manholes may either be round or elliptical. The long axis of an elliptical manhole is to be vertical to or along the length of the ship. Except access openings, the holes in upper and lower adjacent horizontal girders are not to be on the same vertical line. The manhole edges are to be strengthened.

**8.9.2 Structural arrangements of double side skin**

8.9.2.1 Where double side skin is provided in the cargo area, the inner shell is to extend as far forward and aft as practicable at the fore and aft ends of the cargo hold and is to be effectively connected and tapered to the structures there. Supporting members within the inner shell are to be provided in double side skin instead of one side of the cargo hold.

8.9.2.2 Cargo loading is not permitted inside double side skin, and the inner shell is to be so arranged that all cargo holds are inboard of double side skin.

8.9.2.3 Where the load line length $L_L$ is 150 m and upwards, the width of double side skin at any transverse section of the hull is not to be less than 1 m. Such width is the distance between the outer shell and the inner shell, measured perpendicular to the side shell. For double side skin bulk carriers, the width requirement is not restricted by the length of ship.

8.9.2.4 Where the load line length $L_L$ is 150 m and upwards, the structural arrangement of double side skin is to comply with the following:

(1) the minimum width of the clear passage through the double-side skin space in way of obstructions such as piping or vertical ladders is not to be less than 0.6 m;

(2) where the inner and outer skins are transversely framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.6 m;

(3) where the inner and outer skins are longitudinally framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.8 m. Outside the parallel part of the cargo hold length, this clearance may be reduced where necessitated by the structural configuration, but not less than 0.6 m.

Consideration over end brackets of frames is not necessary when measuring the clearance, see Figure 8.9.2.4 for the measurement.

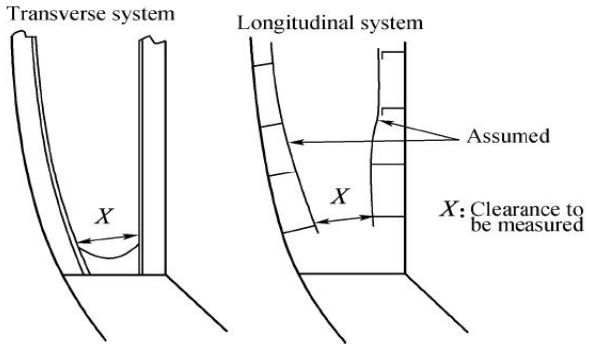



**Figure 8.9.2.4**

8.9.2.5 Transverse webs are to be provided within double side skin in line with the transverse watertight bulkheads of cargo holds. Otherwise, transverse framing is to be provided and ballast tanks are to be provided with swash bulkheads.

8.9.2.6 Transverse framing or transverse webs, which are to be provided or alternately provided within double side skin in line with double bottom transverses, together with transverse supporting members in

topside tanks and hopper tanks and double bottom transverses, form transverse strength framing.
8.9.2.7 Horizontal girders must be provided at bottom of topside tanks and at top of hopper tanks. Manholes may not be provided for the sake of subdivision and stability.

### 8.9.3 Minimum thickness

8.9.3.1 The minimum thickness $t$ of webs and face plates of primary members, horizontal girders, transverse webs and inner shell plating in double side skin is not to be less than that obtained from the following formula:

$$t = 7.5 + 0.015L, \text{ but need not be greater than 11 mm}$$

8.9.3.2 Where specified empty spaces are within double side skin, the minimum thickness as required in 8.9.3.1 may be reduced by 1 mm.

### 8.9.4 Inner shell plating

8.9.4.1 Where specified empty spaces are within double side skin, in addition to complying with the requirement in 8.9.3 of this Section, the thickness $t$ of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from the lower edge of the inner shell plating strake to bulkhead deck;
$K$ — material factor.

Where no hopper tank is provided, the thickness obtained of strake at the bottom of the inner shell plating is to be increased by 1 mm, the width is not to be less than 900 mm. Where the thickness of inner shell plating is much less than that of the girder web to which the shell plating is connected, the thickness of the inner shell plating in way of the connecting area is in general to be increased.
8.9.4.2 Where ballast tanks are within double side skin, in addition to complying with the requirement in 8.9.3 of this Section, the thickness $t$ of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from the lower edge of the inner shell plating strake to the top of the ballast tank, or half the distance to the top of the overflow, whichever is the greater;
$K$ — material factor.
Where no hopper tank is provided, the thickness obtained of the lowest strake of inner shell plating is to be increased by 1 mm.
8.9.4.3 Where no topside tank is provided, the thickness of inner shell plating within $0.1D$ of strength deck is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{DK} \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$D$ — molded depth, in m;
$K$ — material factor.
However, the thickness of inner shell plating is not to be necessarily greater than that of sheer strakes with same frame spacing.
8.9.4.4 Stiffener spacing of inner shell plating is to be the same as that of side frames or side longitudinals.
8.9.4.5 In specified empty spaces, the section modulus $W$ of inner shell plating stiffeners is not to be less than that obtained from the following formula:

$$W = 3shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from the mid-span of the stiffener to upper deck, but not less than 2 m;
$l$ — span of stiffener, in m;
$K$ — material factor.
8.9.4.6 In the ballast tank, the section modulus $W$ and the moment of inertia $I$ of inner shell stiffeners are not to be less than those obtained from the following formulae respectively:

$$W = 8.2shl^2K \quad \text{cm}^3$$
$$I = 2.3Wl/K \quad \text{cm}^4$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from the mid-span of the stiffener to tank top, or half the distance to the top of the overflow, whichever is the greater;
$l$ — span of stiffener, in m;
$K$ — material factor.

8.9.4.7 In ships over 150 m in length or where higher tensile steel is used for horizontal stiffeners, horizontal stiffeners of inner shell plating within 0.1$D$ from bottom and strength deck are to pass continuously through watertight transverse webs. Where horizontal stiffeners are cut at watertight transverse webs, they are to be bracketed to transverse webs.

8.9.4.8 Tripping brackets are to be provided at both ends of vertical stiffeners.

8.9.4.9 Scantlings of tripping brackets are to comply with the requirements in 1.2.6 of Chapter 1 of this PART.

### 8.9.5 Transverse webs

8.9.5.1 Where watertight transverse webs in double side skin constitute boundaries of specified empty spaces, their scantlings are to comply with the requirements in 8.9.4.1 and 8.9.4.5 of this Section.

8.9.5.2 Where watertight transverse webs in double side skin constitute boundaries of ballast tanks, their scantlings are to comply with the requirements in 8.9.4.2 and 8.9.4.6 of this Section.

8.9.5.3 Stiffeners are to be provided in between side longitudinals and inner shell horizontal stiffeners in way of transverse webs.

8.9.5.4 Where longitudinal framing is provided inside double side skin, non-watertight transverse webs supporting side longitudinals and inner shell horizontal stiffeners are to be provided or alternately provided at the same frame of bottom transverse in double side skin. The thickness of non-watertight transverse webs is to comply with the requirements in 8.9.3 of this Section. The side longitudinals and inner shell horizontal stiffeners are to pass through the non-watertight transverse webs.

### 8.9.6 Platform in deep tanks

8.9.6.1 The platform in deep tanks is to comply with the relevant requirements of Section 13, Chapter 2 of this PART.

# Appendix 1 DIRECT STRENGTH CALCULATION OF BULK CARRIERS

## 1 General

### 1.1 General requirements

1.1.1 This Appendix applies to the direct strength calculation of bulk carriers as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

## 2 Design Loads

### 2.1 General requirements

2.1.1 Unless otherwise specified in this Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless otherwise specified in this Appendix, the still water bending moment in the global load condition is to be taken as the permissible value $\overline{M}_s$ provided by the designer, and the wave bending moment $M_w$ is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_{sp}$ is determined by the designer, but it is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual. The sequence of loading and unloading is to be indicated in the loading manual.

## 3 Loading Conditions

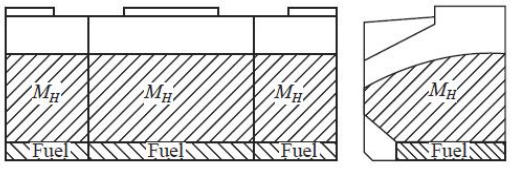
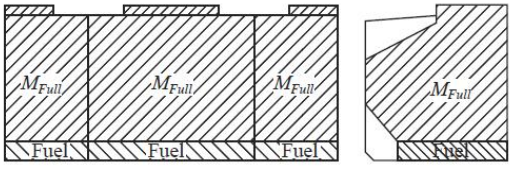
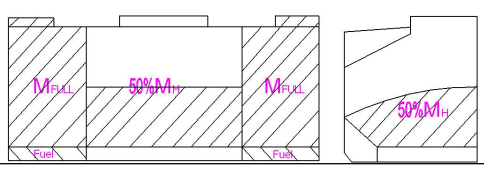
### 3.1 General requirements

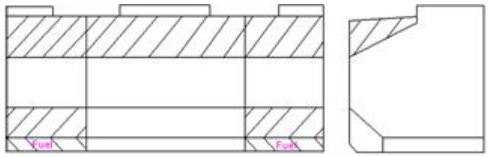
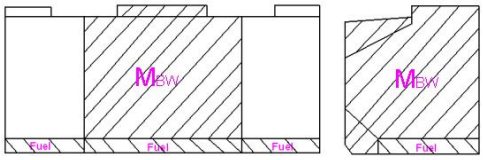
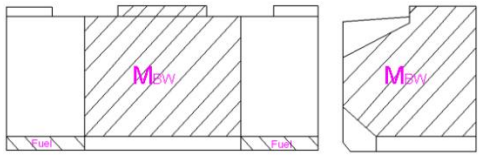
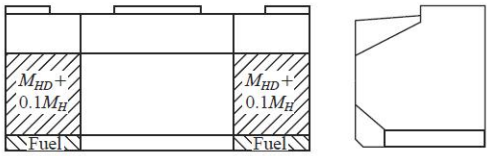
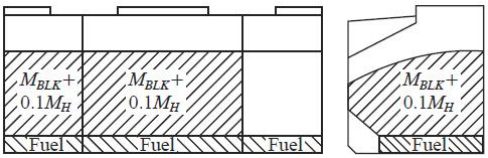
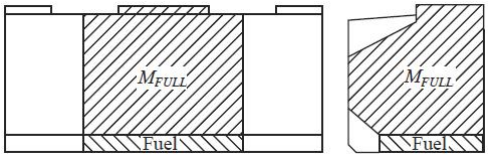
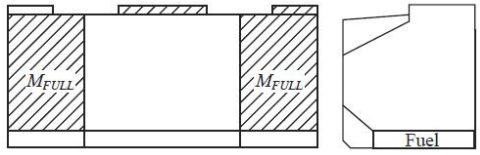
3.1.1 Normally, the loading conditions under consideration are to cover the most severe condition in ship design. The corresponding loading conditions are to be selected from Table 3.2.1 of this Appendix for check. For more severe loading conditions in the loading manual which are not covered by the Table, direct strength analysis is also to be carried out.

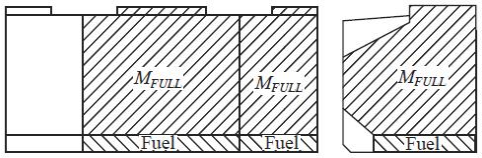
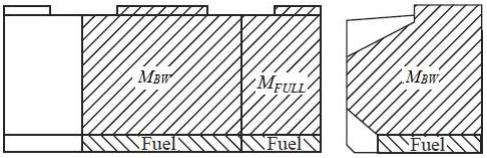
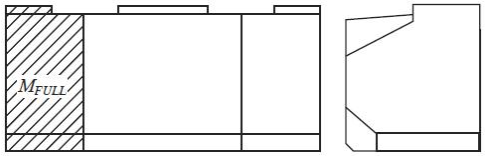
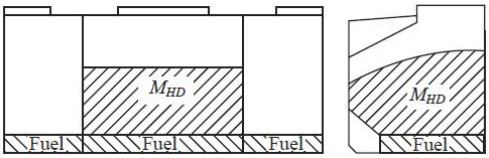
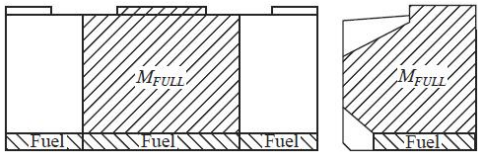
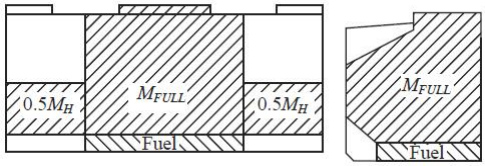
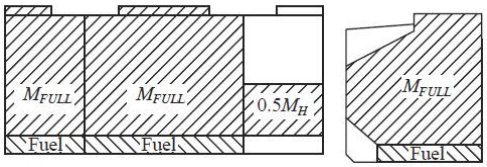
### 3.2 Loading conditions

3.2.1 The finite element analysis for holds is to be carried out in accordance with the applicable loading conditions in Table 3.2.1.

**Loading Conditions** **Table 3.2.1**

| Type of loading condition | Loading condition no. | Condition considered | Mode of loading | Still water bending moment | Wave bending moment |
|---|---|---|---|---|---|
| Full load | 1 | Full load |  Draught = $d$ | $\overline{M}_s$ | $M_w$ |
| | 2 | Full load |  Draught = $d$ | $\overline{M}_s$ | $M_w$ |
| | 3 | Non-homogeneous full load |  | 1.1 $M_a$, but need not be greater than $\overline{M}_s$, taken as $\overline{M}_s$ if there is no such loading | $M_w$ |

| Type of loading condition | Loading condition no. | Condition considered | Mode of loading | Still water bending moment | Wave bending moment |
|---|---|---|---|---|---|
| | | | Draught = $d$ | condition | |
| Ballast | 4 | Normal ballast |  Draught = deepest ballast draught | $\overline{M}_s$ | $M_w$ |
| | 5 | Heavy ballast |  Draught = heavy draught | $\overline{M}_s$ | $M_w$ |
| | 6 | Heavy ballast |  Draught = heavy draught | $\overline{M}_s$ | $M_w$ |
| Alternate load | 7 | Alternate load |  Draught = $d$ | $\overline{M}_s$ | $M_w$ |
| | 8 | Alternate load |  Draught = $d$ | $\overline{M}_s$ | $M_w$ |
| | 9 | Alt-block load |  Draught = $d$ | $\overline{M}_s$ | $M_w$ |
| Loading/ Unloading in multiple ports | 10 | Multi port - 1 |  Draught = 0.67$d$ | $\overline{M}_s$ | $M_w$ |
| | 11 | Multi port - 2 |  | $\overline{M}_s$ | $M_w$ |

| Type of loading condition | Loading condition no. | Condition considered | Mode of loading | Still water bending moment | Wave bending moment |
|---|---|---|---|---|---|
| | | | Draught = 0.83$d$ | | |
| | 12 | Multi port – 3a |  Draught = 0.67$d$ | $\overline{M}_s$ | $M_w$ |
| | 13 | Multi port – 3b |  Draught = 0.67$d$ | $\overline{M}_s$ | $M_w$ |
| | 14 | Multi port - 4 |  Draught = 0.75$d$ | $\overline{M}_s$ | $M_w$ |
| Loading/ Unloading in harbour | 15 | Harbour condition -1a |  Draught = 0.67$d$ | $\overline{M}_{sp}$ | — |
| | 16 | Harbour condition - 1b |  Draught = 0.67$d$ | $\overline{M}_{sp}$ | — |
| | 17 | Harbour condition - 1c |  Draught = 0.67$d$ | $\overline{M}_{sp}$ | — |
| | 18 | Harbour condition - 2 |  draught=0.67$d$ | $\overline{M}_{sp}$ | — |

Notes:

$M_a$ — actual still water bending moment in the corresponding condition, in kN·m;

$M_H$ — actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t;

$M_{FULL}$ — cargo mass in a cargo hold corresponding to cargo with virtual density filled to the top of the hatch coaming, in t, i.e.:

$$M_{FULL} = V_{FULL} \bullet \max(M_H / V_{FULL}, 1.0)$$

$M_{HD}$ — maximum cargo mass allowed to be carried in a cargo hold according to design loading condition with specified holds empty at maximum draught, in t;

$M_{BW}$ — maximum ballast water mass in cargo holds, in t;

$M_{BLK}$ — maximum cargo mass under packed cargo conditions, in t;

$V_H$ — volume, in $m^3$, of cargo hold excluding the volume enclosed by hatch coaming;

$V_{FULL}$ — volume, in $m^3$, of cargo hold including the volume enclosed by hatch coaming;

$\rho_w$ — density of sea water, to be taken as 1.025 $t/m^3$.

## 4 Structural Modeling

### 4.1 General requirements

4.1.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

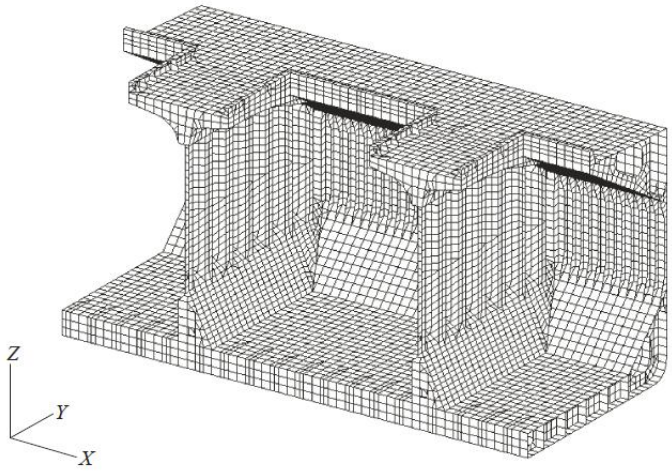



**Figure 4.1.1 Finite Element Model**

### 4.2 Boundary conditions

4.2.1 Boundary condition with the structures symmetrical to longitudinal centerline section

4.2.1.1 If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotation around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta_y = \theta_x = \theta_z = 0$.

4.2.1.2 If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo holds and bottom plating are restrained, i.e.: $\delta_y = 0$.

4.2.2 Boundary conditions for local loads (see Table 4.2.2)

4.2.2.1 Symmetrical boundary conditions are applied respectively to end planes *A* and *B*, and the displacements in longitudinal direction of nodes within the end plane and the rotations around the two coordinate axes within the end plane are restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.2.2 Vertical spring elements are to be provided at intersections of side shell plating and inner hull plating with forward and aft transverse bulkheads in midship holds. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: $G$ — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ $N/mm^2$ for steel;

$A$ — shearing area of side shell plating and inner hull plating in way of forward and aft bulkheads, in $mm^2$;

$l_H$ — length of midship hold, in mm;

$n$ — number of nodes on vertical intersections of side shell plating and inner hull plating.

**Boundary Conditions for Local Loads** **Table 4.2.2**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Longitudinal centerline section (half-breadth model) | – | Constraint | – | Constraint | – | Constraint |
| Node *G* (full-breadth model) | – | Constraint | – | – | – | – |
| End planes *A*, *B* | Constraint | – | – | – | Constraint | Constraint |
| Intersection line *C* | – | – | Spring | – | – | – |

4.2.3 Boundary conditions for global load (see Table 4.2.3)

4.2.3.1 An independent point *H* is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the longitudinal bending moment is to be applied on the point *H*, and the degrees of freedom $\delta_x$, $\delta_y$ and $\delta_z$ of each member node for end planes is linked to independent point.

4.2.3.2 The displacements of the independent point *H* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$ ; the displacement of the independent point *H* within the end plane *A* in longitudinal direction are restrained, i.e.: $\delta_x = 0$ .

**Boundary Conditions for Global Load** **Table 4.2.3**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Longitudinal centerline section (half-breadth model) | – | Constraint | – | Constraint | – | Constraint |
| Node *G* (full-breadth model) | – | Constraint | – | – | – | – |
| End planes *A*, *B* | Link | Link | Link | – | – | – |
| Independent point *H* (end plane *A*) | Constraint | Constraint | Constraint | Constraint | Bending moment | – |
| Independent point *H* (end plane *B*) | – | Constraint | Constraint | Constraint | Bending moment | – |

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

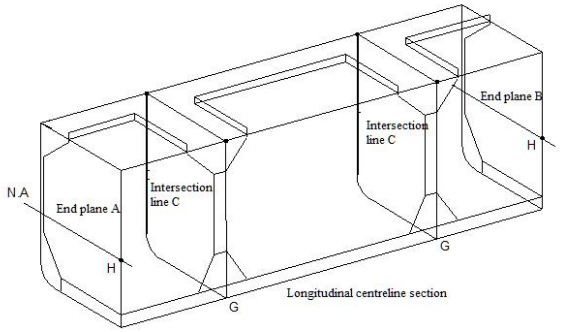



**Figure 4.2.4 Boundary Conditions**

## 5 Yield Strength Evaluation

### 5.1 Allowable stresses

5.1.1 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent. The stress evaluated is to be the combined one due to local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

5.1.2 The allowable stresses for each primary structural member are given in Table 5.1.2.

**Allowable Stresses** **Table 5.1.2**

| Type of structures | Allowable stress (N/mm$^2$) | |
|---|---|---|
| | $[\sigma_e]$ | $[\tau]$ |
| Deck | 220/K | – |
| Bottom shell plating, inner bottom plating | 220/K | – |
| Side shell plating, inner skin plating, horizontal girder in double hulls | 220/K | 115/K |
| Hopper and topside tank sloping plating | 220/K | 115/K |
| Bottom girder | 235/K | 115/K |
| Double bottom floor | 175/K | 95/K |
| Transverse bulkhead | 175/K | 95/K |
| Side plating of lower and upper stools | 195/K | 95/K |
| Transverse web frame | 195/K | 95/K |
| Deck between hatchways | 175/K | – |
| Other | 195/K | – |

Note: *K*— material factor.

## 6 Buckling Strength Evaluation

### 6.1 Buckling safety factors

6.1.1 The standard thickness deduction of members is given in Table 6.1.1.

**Standard Thickness Deduction** **Table 6.1.1**

| Position | | Standard thickness deduction (mm) |
|---|---|---|
| Within 1.5 m below weather deck | One side connected to ballast water | 1.0 |
| | Two sides connected to ballast water | 2.0 |
| Elsewhere | | 1.0 |

6.1.2 The safety factor $\lambda$ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

**Minimum Buckling Safety Factor** **Table 6.1.2**

| Structural member | Minimum buckling safety factors | Structural member | Minimum buckling safety factors |
|---|---|---|---|
| Deck, deck between hatchways | 0.8 | Double bottom girder, horizontal girder in double hulls | 1.0 |
| Bottom shell plating, inner bottom plating | 0.8 | Double bottom floor, transverse web frame | 1.0 |
| Side shell plating, inner skin plating | 0.8 | Transverse bulkhead, lower stool, upper stool | 0.8 |
| Hopper and topside tank sloping plating | 0.8 | | |

# Appendix 2 HOLD MASS CURVES

Symbols

$h$ : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section, in m;

$h_a$ : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of aft cargo holds under the alt-block loading condition, in m;

$h_f$ : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of forward cargo holds under the alt-block loading condition, in m;

$M_H$ : see Appendix 1 of this Chapter;

$M_{FULL}$ : see Appendix 1 of this Chapter;

$M_{HD}$ : see Appendix 1 of this Chapter;

$M_D$ : maximum cargo mass given for each cargo hold, in t;

$M_{BLK}$ : see Appendix 1 of this Chapter;

$T_{HB}$ : maximum ballast draught, in m;

$T_i$ : draught in loading condition No. $i$ at mid-hold position of cargo hold length $l_H$, in m;

$d$ : draught, in m;

$V_H$ : volume, in $m^3$, of cargo hold excluding the volume enclosed by hatch coaming;

$V_f$, $V_a$ : volume, in $m^3$, of forward or aft cargo hold excluding the volume enclosed by hatch coaming;

$T_{min}$ : 0.75 $d$ or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m;

$\Sigma$ : sum of mass of two adjacent cargo holds.

## 1 General Requirements

### 1.1 Application

1.1.1 This Appendix applies to ships of 150 m or over in length.

1.1.2 This Appendix describes the procedure to be used for determination of:

(1) the maximum and minimum masses of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold;

(2) the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

1.1.3 The calculation results are to be included in the loading manual.

## 2 Maximum and Minimum Masses of Cargo in Each Hold

### 2.1 Maximum permissible mass and minimum required mass of single cargo hold in sea-going condition

2.1.1 The cargo mass curves of single cargo hold in sea-going condition are defined in 2.1.2 to 2.1.5 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.1.2 Ships with alternate load under multi-port condition

For loaded holds, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(d - T_i)}{h}$$

$W_{max}(T_i)$ in no case to be greater than $M_{HD}$.

For loaded holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \le 0.83d$$

$$W_{\min}(T_i) = 1.025V_H \frac{(T_i - 0.83d)}{h} \qquad \text{for } d \ge T_i > 0.83d$$

For empty holds which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

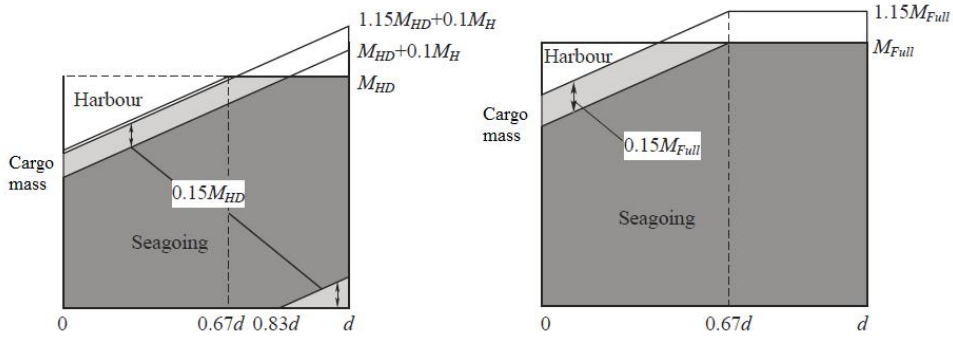
$$W_{\max}(T_i) = M_{Full} \qquad \text{for } d \ge T_i \ge 0.67d$$

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} \quad \text{for } T_i < 0.67d$$

For loaded holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under multi-port condition are shown in Figure 2.1.2.




(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

**Figure 2.1.2 Mass Curve for Ships with Alternate Load under Multi-port Condition**

2.1.3 Ships with alternate load under no multi-port condition

For cargo holds, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$), in t, is the same as specified in 2.1.2.

For cargo holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = \min \begin{cases} 1.025V_H \dfrac{(T_i - T_{HB})}{h} & \text{for } d \geq T_i > T_{HB} \\ 0.5M_H - 1.025V_H \dfrac{(d - T_i)}{h} \geqslant 0 & \text{for } d \geq T_i \end{cases}$$

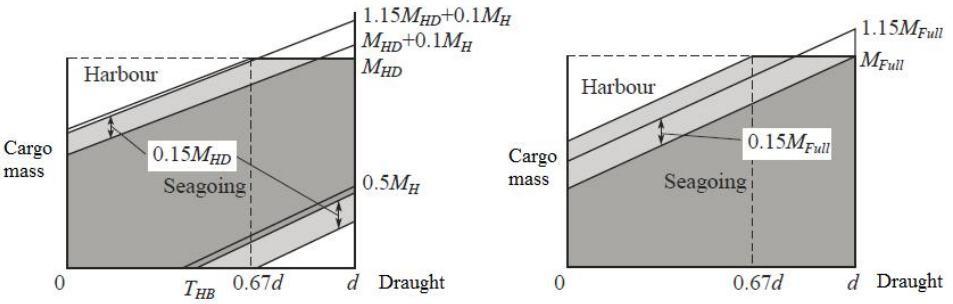
For empty hold which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draught ($T_i$) is obtained, in t, by the following formula:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

For empty hold which may be empty at the maximum draught, the minimum required cargo mass ($W_{min}(T_i)$) at various draught ($T_i$) is obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under no multi-port condition are shown in Figure 2.1.3.




(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

**Figure 2.1.3 Mass Curve for Ships with Alternate Load under no Multi-port Condition**

2.1.4 Ships with homogeneous load under multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following

formulae:

$$W_{\max}(T_i) = M_{Full} \qquad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.83d$$

$$W_{\min}(T_i) = 1.025V_H \frac{(T_i - 0.83d)}{h} \qquad \text{for } d \geq T_i > 0.83d$$

Mass curves of loaded cargo hold for ships with homogeneous load under multi-port condition are shown in Figure 2.1.4.

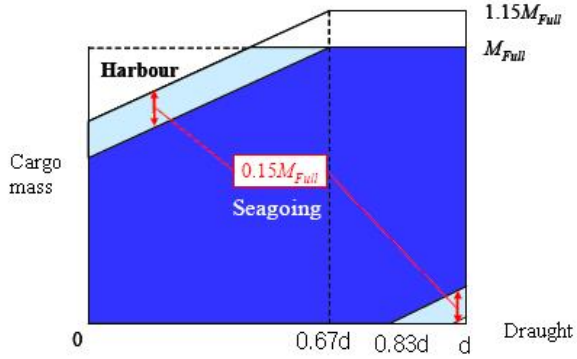



**Figure 2.1.4 Mass Curve for Ships with Homogeneous Load under Multi-port Condition**

2.1.5 Ships with homogeneous load under no multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formula:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = \min \begin{cases} 1.025V_H \dfrac{(T_i - T_{HB})}{h} \geqslant 0 & \text{for } d \geq T_i > T_{HB} \\ 0.5M_{\mathrm{H}} - 1.025V_{\mathrm{H}} \dfrac{(d - T_{\mathrm{i}})}{h} \geqslant 0 & \text{for } d \geq T_i \end{cases}$$

Mass curves of loaded cargo hold for ships with homogeneous load under no multi-port condition are shown in Figure 2.1.5.

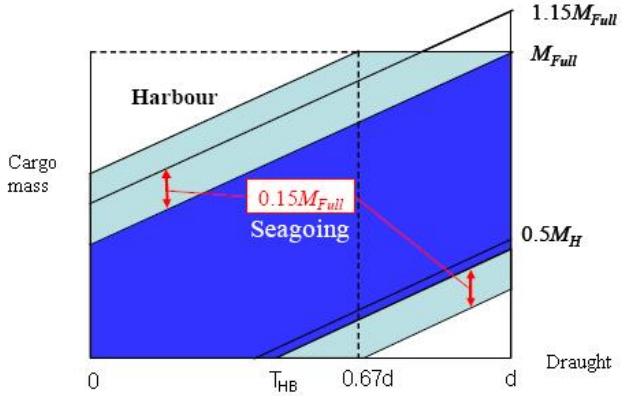



**Figure 2.1.5 Mass Curve for Ships with Homogeneous Load under No Multi-port Condition**

## 2.2 Maximum permissible mass and minimum required mass of single cargo hold in harbour

**condition**

2.2.1 The cargo mass curves of single cargo hold in harbour condition are defined in 2.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

2.2.3 Ships with alternate load under multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts ($T_i$) is to be checked by the following formulae, in addition to the requirements of 2.1.2 of this Appendix:

For cargo hold,

$$W_{\max}(T_i) = M_{HD} \qquad \text{for } T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{HD} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

2.2.4 Ships with alternate load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts ($T_i$) is to be checked by the following formulae, in addition to the requirements of 2.1.3 of this Appendix:

For empty hold which may be empty at the maximum draught,

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

2.2.5 Ships with homogeneous load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts ($T_i$) is to be checked by the following formulae, in addition to the requirements of 2.2.2 of this Appendix:

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } d \geq T_i > 0.67d$$

$$W_{\max}(T_i) = M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

## 3 Maximum and Minimum Cargo Masses of Two Adjacent Holds

### 3.1 Maximum permissible cargo mass and minimum required cargo mass of two adjacent holds in sea-going condition

3.1.1 The cargo mass curves of two adjacent cargo holds in sea-going condition are defined in 3.1.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.1.2 Ships with alternate load of bulk goods under multi-port condition

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(d - T_i)$$

or

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67d - T_i)$$

$W_{\max}(T_i)$ is not greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - 0.75\mathrm{d}) \quad \text{for } d \geq T_i > 0.75d.$$

3.1.3 Ships with alternate load of packed cargo under no multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(d - T_i)$$

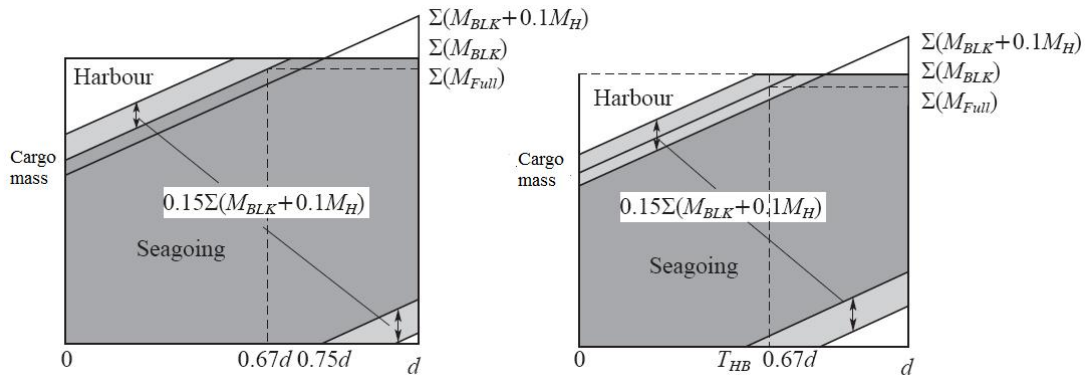
$W_{\max}(T_i)$ is not greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}.$$

Mass curves of loaded cargo hold for ships with alternate load of packed cargo are shown in Figure 3.1.3.




(a) Under multi-port condition (b) Under no multi-port condition

**Figure 3.1.3 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load of Packed Cargo**

3.1.4 Ships with alternate load without packed cargo under multi-port condition and ships with homogeneous load

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum M_{FULL} \qquad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(0.67d - T_i) \qquad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - 0.75\mathrm{d}) \qquad \text{for } d \geq T_i > 0.75d$$

3.1.5 Ships with alternate load without packed cargo under no multi-port condition and ships with homogeneous load

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formula:

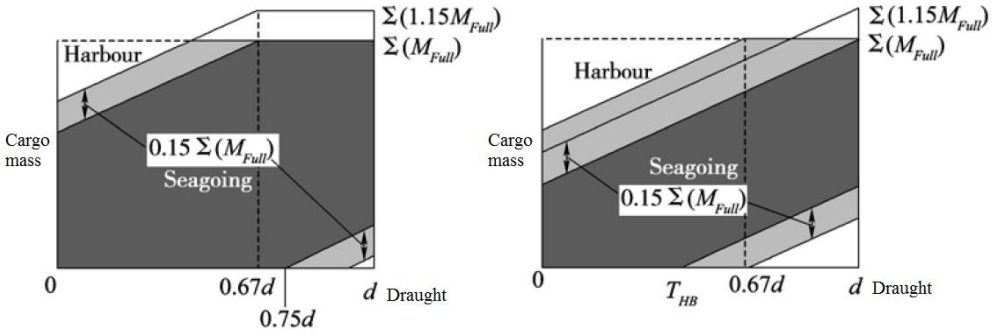
$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(d - T_i) \qquad \text{for } T_i < d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts ($T_i$) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}$$

Mass curves of loaded cargo hold for ships with alternate load without packed cargo are shown in Figure 3.1.5.




(a) Under multi port condition (b) Under no multi port condition

**Figure 3.1.5 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load without Packed Cargo and Ships with Homogeneous Load**

**3.2 Maximum permissible cargo mass and minimum required cargo mass in two adjacent holds in harbour condition**

3.2.1 The cargo mass curves of two adjacent cargo holds in harbour condition are defined in 3.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

3.2.3 Ships with alternate load of packed cargo under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts ($T_i$) is to be checked by the following formulae, in addition to the requirements of 3.1.3 of this Appendix:

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(0.67d - T_i)$$

$$W_{\max}(T_i) \leq M_{BLK}$$

3.2.4 Ships with alternate load without packed cargo under no multi-port condition and ships with homogeneous load

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts ($T_i$) is to be checked by the following formulae, in addition to the requirements of 3.1.5 of this Appendix:

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(0.67d - T_i) \qquad \text{for } T_i < 0.67d$$

# CHAPTER 9 ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

## Section 1 GENERAL PROVISIONS

### 9.1.1 Application

9.l.l.1 This Chapter applies to roll on-roll off ships, passenger ships, ro-ro passenger ships and ferries defined as follows:

(1) A roll on-roll off ship is a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles.

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

(3) Ro-ro passenger ship means a passenger ship with ro-ro cargo spaces or special category spaces.

(4) Ferries are the ships specially designed for the carriage of passengers (without sleeping berths) and/or vehicles engaged on regular voyages between two sides of straits or islands. Ferries carrying more than 12 passengers are ferry passenger ships.

9.1.1.2 Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

9.1.1.3 Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

9.1.1.4 Those not specified in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

### 9.1.2 Plans and documents

9.1.2.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following plans and documents are to be submitted for approval:

(1) Structural arrangement of ramps (appropriate strength calculations are submitted for information);

(2) Structural arrangements of bow doors, inner doors, stern doors and side doors and their operating and maintenance manual (appropriate strength calculations are submitted for information);

(3) Structural arrangement of movable platforms (appropriate strength calculations are submitted for information);

(4) Structural arrangement of sloping vehicle ramps (appropriate strength calculations are submitted for information).

9.1.2.2 Direct strength calculations for vehicle deck (where available), direct calculations of transverse strength for hull (where applicable), the arrangement of wheel prints for the carriage of vehicles and the data related to design loading, e.g. loads and axle loads, are to be provided for information.

## Section 2 HULL STRUCTURE

### 9.2.1 General requirements

9.2.1.1 The structural arrangements of hull are to comply with the relevant requirements of Section 8, Chapter 1 of this PART.

9.2.1.2 The basic structural configuration is to be a single deck or multi-deck hull, and in some cases wing tanks up to the freeboard deck or bulkhead deck may be fitted.

9.2.1.3 Where the number of transverse bulkheads is not in accordance with the requirements in Section 12, Chapter 2 of this PART, a system of partial transverse bulkheads, web frames and deck transverses are to be fitted to provide equivalent transverse strength.

9.2.1.4 Longitudinal framing is, in general, to be adopted at the strength deck and at the bottom for ships greater than 65 m in length.

9.2.1.5 Web frames and deck transverses within the vehicle hold area above the bulkhead deck may be connected with continuous rounded corners or cross joints of bracketless connections, see Figure 9.2.1.5(1)

and 9.2.1.5(2). The radius $R$ of the rounded corners is not to be less than the web depth of web frame or deck transverse, whichever is greater. The web thickness $t_3$ of the joint of cross connection without brackets (between web frame and deck transverse) is not to be less than the greater of the values obtained by following formulas, nor less than the web thickness of web frame or deck transverse, whichever is greater.

$$t_3 = \frac{1}{K}\left(\frac{\sigma_1 A_1}{dw_2} - \frac{t_2 \tau_2}{100}\right) \quad \text{mm}$$

$$t_3 = \frac{1}{K}\left(\frac{\sigma_2 A_2}{dw_1} - \frac{t_1 \tau_1}{100}\right) \quad \text{mm}$$

where: $A_1$, $A_2$ — section area of faceplate respectively of web frame and deck transverse, in cm$^2$;

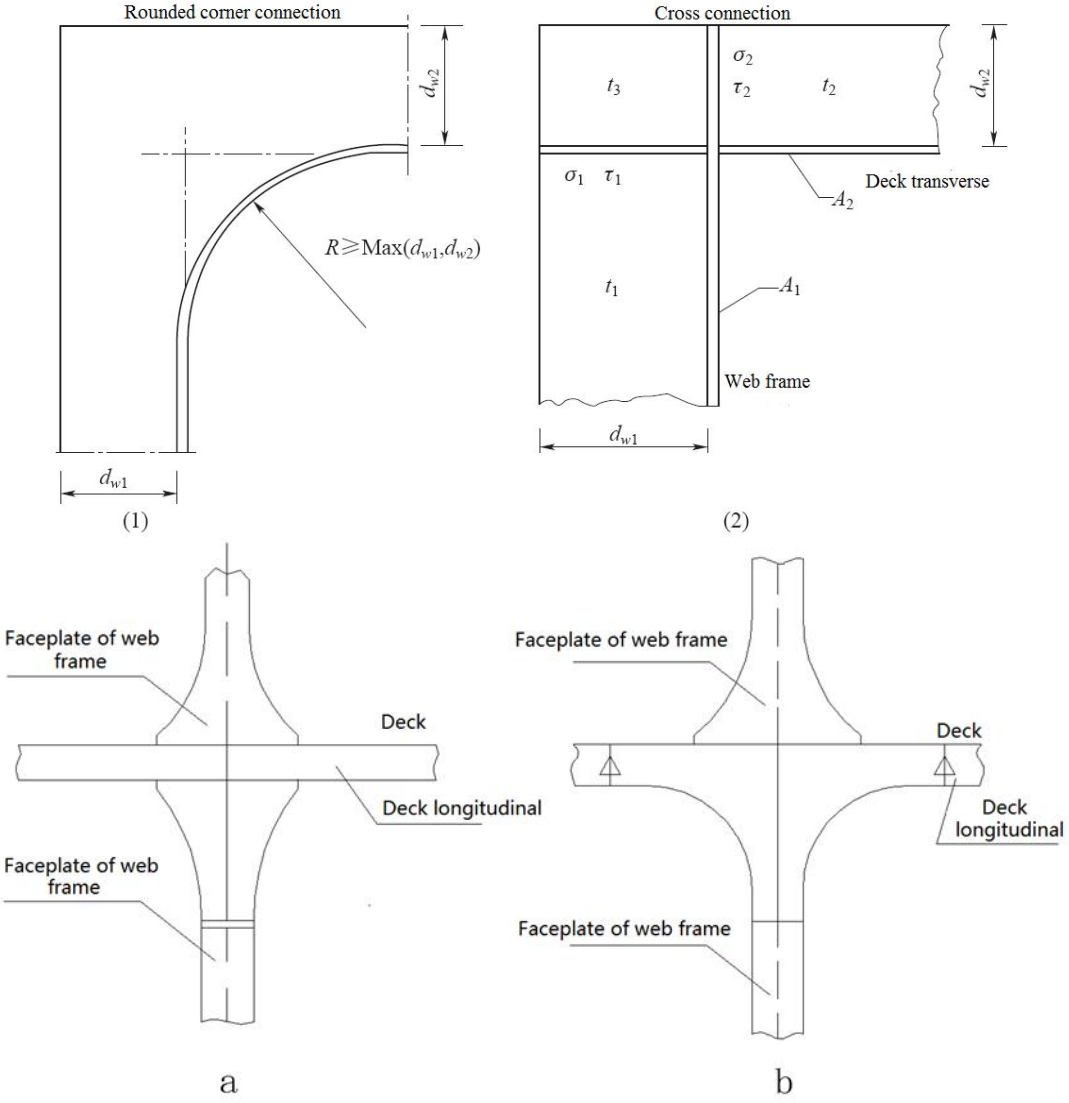
$dw_1$, $dw_2$ — web depth respectively of web frame and deck transverse, in mm;

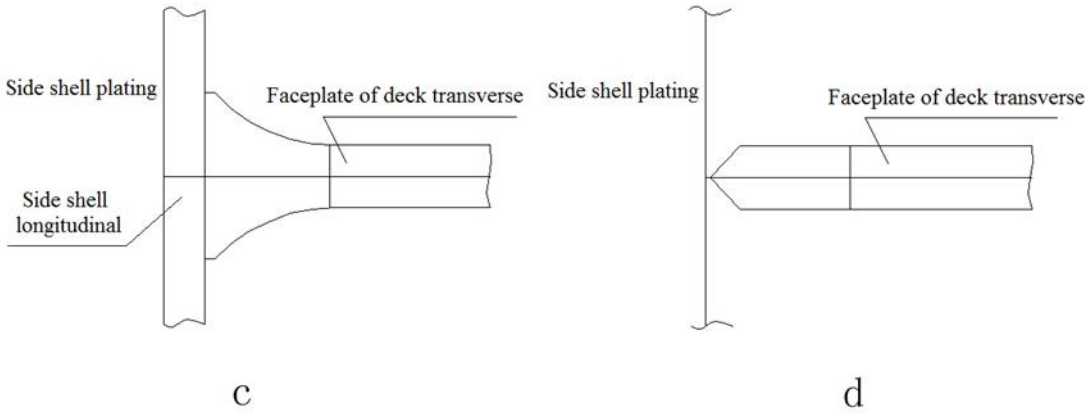
$t_1$, $t_2$— web thickness respectively of web frame and deck transverse adjacent to cross connection joint, in mm;

$\sigma_1$, $\sigma_2$— bending stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm$^2$;

$\tau_1$, $\tau_2$ — shear stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm$^2$;

$K$ — material factor.






(3)

**Figure 9.2.1.5**

The faceplate of web frames and deck transverses, which are cross-connected without brackets, is to be continuous to deck plating and side shell and to be well transitioned, see Figure 9.2.1.5(3) for typical types of joints.

9.2.1.6 Where necessary, the structures in way of securing devices of vehicles and securing points of the hull are to be locally strengthened as appropriate.

9.2.1.7 The scantlings of stabilizing tanks and balancing tanks are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks. The scantlings of those members, which may be subject to sloshing loads, are to be increased by 10%.

### 9.2.2 Longitudinal strength

9.2.2.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART. Where large openings are cut in side shell below strength deck and this significantly reduces shear force transmission from side shell to strength deck, the contribution of longitudinal continuous members within the area of strength deck and openings below to the longitudinal strength may be determined by finite element direct calculations.

### 9.2.3 Transverse strength

9.2.3.1 For roll on-roll off ships, ro-ro passenger ships and ferries, the transverse strength of hull is to be checked in accordance with the relevant requirements of Section 7 of this Chapter.

### 9.2.4 Superstructure deck

9.2.4.1 Where superstructure deck is strength deck, the thickness of deck plating, excluding that of the forecastle, is to comply with the requirements of 2.17.5.4, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter, but not less than 6 mm.

9.2.4.2 Where superstructure deck is strength deck, the framing of superstructure deck is to comply with relevant requirements in Section 8, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter.

### 9.2.5 Side framing

9.2.5.1 Side framing is to comply with the requirements of Section 7, Chapter 2 of this PART. When calculating the scantlings of primary members of side framing below freeboard deck, however, the design pressure head may be measured to freeboard deck at side.

### 9.2.6 Vehicle deck

9.2.6.1 The structure of vehicle deck is to comply with the requirements of Section 21, Chapter 2 of this PART.

9.2.6.2 The strength of primary supporting members of vehicle deck is to comply with relevant requirements in Section 7 of this Chapter.

### 9.2.7 Train deck

9.2.7.1 Rails on the deck are to be fitted in way of deck girders or longitudinals. The effects of rails on the structural strength are not to be considered.
9.2.7.2 The thickness of deck plating is to be in accordance with relevant requirements in Section 4, Chapter 2 of this PART.
9.2.7.3 The longitudinals or beams of deck framing are to be in accordance with relevant requirements in Section 8, Chapter 2 of this PART, and design head $h$ is to be taken as $0.14p$, $p$ being design cargo load, in kPa. Deck longitudinals supporting rails are to comply with relevant requirements of Section 21, Chapter 2 of this PART.
9.2.7.4 The girders and transverses of deck framing are to be in accordance with relevant requirements in 2.21.2.3, Section 21, Chapter 2 of this PART. Where the deck framing is fitted with transverses and girders, their scantlings may be determined by direct calculations in accordance with Section 7 of this Chapter. The load of train wheels and the concentrated static load at supporting points of lifting jacks are to be taken into account respectively.
9.2.7.5 Where the train deck is intended to carry road vehicles, relevant requirements in this Chapter for vehicle decks are to be complied with.
9.2.7.6 Where jacks are used to secure trains, the supporting points of the jacks are to be arranged as far as practicable in way of primary supporting members of the deck structure, otherwise the structure in this area is to be locally strengthened.

### 9.2.8 Deck framing within area of deckhouses in accommodation spaces

9.2.8.1 Section modulus $W$ of deck longitudinals or beams within area of deckhouses is not to be less than the value obtained as follows:

$$W = 5shl^2K \quad \text{cm}^3\text{, and not less than } 25s$$

where: $s$ — spacing of deck longitudinals or beams, in m;
$l$ — span of deck longitudinals or beams, in m;
$h$ — design head, in m, taken as 0.45 m and for portions exposed to weather, increased by $h_0$ - 1.2 m where $h_0$ is to be calculated according to 2.8.1.1 of Chapter 2 of this PART;
$K$ — material factor.

The scantlings of deck girders and transverses within area of deckhouses are to be calculated in accordance with relevant requirements in Section 8, Chapter 2 of this PART, while the design head is to be taken as 0.45 m and web thickness of deckhouse girders is not to be less than 1% of web depth plus 2 mm, nor less than 4 mm.

### 9.2.9 Deck framing within area of deckhouses in baggage and storage spaces

9.2.9.1 For deck framing within area of deckhouses, calculations are to be in accordance with the requirements in Section 8, Chapter 2 of this PART for cargo decks not exposed to weather.

## Section 3 MOVABLE PLATFORMS AND SLOPING VEHICLE RAMPS

### 9.3.1 Movable platforms

9.3.1.1 Movable platforms are generally to be constructed as pontoons comprising a top decking with framing below.
9.3.1.2 Positive means of control are to be provided to secure the platform in position.
9.3.1.3 The supporting means of movable platforms are to have sufficient strength, and are to be designed and strength checked on the basis of the imposed load including the weight of the platform for the fittings or members in way of the following supports:
(1) Flexible supports: such as chains, steel hawser and other fittings, the permissible load is to be taken as 1/5 of the breaking strength.
(2) Rigid supports: the allowable stresses are to be as follows:

Allowable bending stress $[\sigma] \leq 85/K$ N/mm$^2$
Allowable shear stress $[\tau] \leq 43/K$ N/mm$^2$
Allowable equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leqslant 108/K$ N/mm$^2$

where: $K$ — material factor.
(3) Buckling is to be checked to the pressured members.
9.3.1.4 The thickness of the pontoon deck plating is to be calculated as that of the wheeled vehicle decks.
9.3.1.5 Where the movable platforms are intended for handling cargo with forklifts, the scantlings of the stiffeners are to comply with the requirements for deck beams or longitudinals in Section 21, Chapter 2 of

this PART.

9.3.1.6 The section modulus $W$ of the pontoon stiffeners for decks designed for the carriage of vehicles only is not to be less than that obtained from the following formula:

$$W = 1.39 J_1 P l K \quad \text{cm}^3$$

where: $J_1$, $P$ and $l$ — see 2.21.2.2(2) of Chapter 2 of this PART;

$K$— material factor.

9.3.1.7 The scantlings of girders of movable platforms may be determined by a direct calculation on the basis of the following standards:

Allowable bending stress $[\sigma] \leq 128/K$ N/mm$^2$

Allowable shear stress $[\tau] \leq 64/K$ N/mm$^2$

Allowable equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leq 160/K$ N/mm$^2$;

Deflection $f \leq l/400$ mm

where: $K$ — material factor;

$l$ — distance between the supporting points of frames, in mm.

### 9.3.2 Sloping vehicle ramps

9.3.2.1 Fixed sloping vehicle ramps are to comply with the requirements for vehicle decks in Section 21, Chapter 2 of this PART.

9.3.2.2 Movable sloping vehicle ramps are to comply with the requirements for vehicle ramps in Section 6 of this Chapter, and their rigid supports are to comply with 9.3.1.3(2).

## Section 4 BOW DOORS AND INNER DOORS

### 9.4.1 General requirements

9.4.1.1 Application

(1) This Section applies to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

(2) This Section is applicable to the following two types of bow doors:

① **Visor doors** opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

② **Side-opening doors** opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door will be specially considered.

9.4.1.2 Arrangement

(1) Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

(2) An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, refer to 1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART, as appropriate to the type of ship. A vehicle ramp may be arranged for this purpose, provided its position complies with 1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART, as appropriate to the type of ship. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

(3) Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

(4) Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 9.4.1.2 (2) of this Section.

(5) The requirements for inner doors are based on the assumption that vehicle are effectively lashed and secured against movement in stowed position.

9.4.1.3 Definitions

(1) **Securing device**: a device used to keep the door closed by preventing it from rotating about its hinges.

(2) **Supporting device**: a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

(3) **Locking device**: a device that locks a securing device in the closed position.

(4) **Ro-ro passenger ship**: see 9.1.1.1(3) of Section 1 of this Chapter.

(5) **Ro-ro spaces**: see 9.1.1.2 of Section 1 of this Chapter.

(6) **Special category spaces:** see 9.1.1.3 of Section 1 of this Chapter.

### 9.4.2 Strength criteria of primary structure and securing and supporting devices

9.4.2.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be determined to withstand the design loads defined in 9.9.3, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K$ N/mm$^2$

Permissible shear stress $[\tau] = 80/K$ N/mm$^2$

Permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 150/K$ N/mm$^2$

where: $K$ – material factor, but not to be taken less than 0.72 unless a direct fatigue analysis is carried out.

9.4.2.2 The buckling strength of primary members is to be verified as being adequate.

9.4.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8R_{eH}$, where $R_{eH}$ is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

9.4.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, in N/mm$^2$.

### 9.4.3 Design loads

9.4.3.1 Bow doors

(1) The design external pressure $P_e$, in kN/m$^2$, to be considered for the scantlings of primary members, securing and supporting devices of bow doors is not to be less than that obtained from the following formula:

$$P_e = 2.75\lambda C_H (0.22 + 0.15\tan\alpha)(0.4V\sin\beta + 0.6\sqrt{L})^2 \quad \text{kN/m}^2$$

where: $V$ — contractual ship's speed, in kn;

$L$ — ship's length, in m, but need not be taken greater than 200 m;

$\lambda$ — coefficient depending on the area where the ship is intended to be operated:

$\lambda = 1.0$ for ships intended for unrestricted service and greater coastal service;

$\lambda = 0.8$ for ships intended for coastal service;

$\lambda = 0.5$ for ships intended for sheltered water service;

$C_H$ — coefficient, to be determined as follows:

$C_H = 0.0125L$ for $L < 80$ m;

$C_H = 1$ for $L \geq 80$ m;

$\alpha$— flare angle at the point to be considered, defined as the angle between a vertical line; and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, the calculated point on the bow door, $l/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, see Figure 9.4.3.1(1);

$l$— length of the door on the plane $h/2$ above bottom of the door, in m, see Figure 9.4.3.1(1);

$\beta$ — entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centerline and the tangent to the shell plating in a horizontal plane. The calculated point is to be the same as that of angle α, see Figure 9.4.3.1(1).

$h$ — height, in m, of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser.

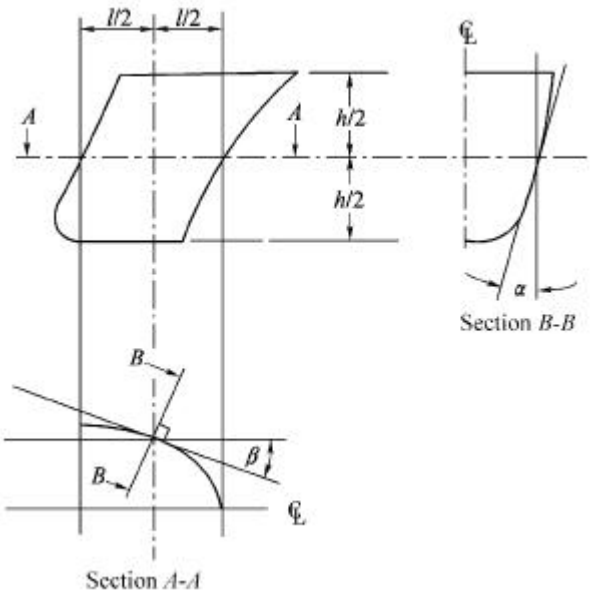



**Figure 9.4.3.1(1)**

(2) The design external forces, in kN, considered for the scantlings of securing and supporting devices of bow doors are to be determined by the following formulae:

$$F_x = P_e A_x \quad \text{kN}$$
$$F_y = P_e A_y \quad \text{kN}$$
$$F_z = P_e A_z \quad \text{kN}$$

where: $A_x$ – area, in $m^2$, of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded. See Figure 9.4.3.1(2);

$A_y$ – area, in $m^2$, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flange angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 9.4.3.1(2);

$A_z$ – area, in $m^2$, of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 9.4.3.1(2).

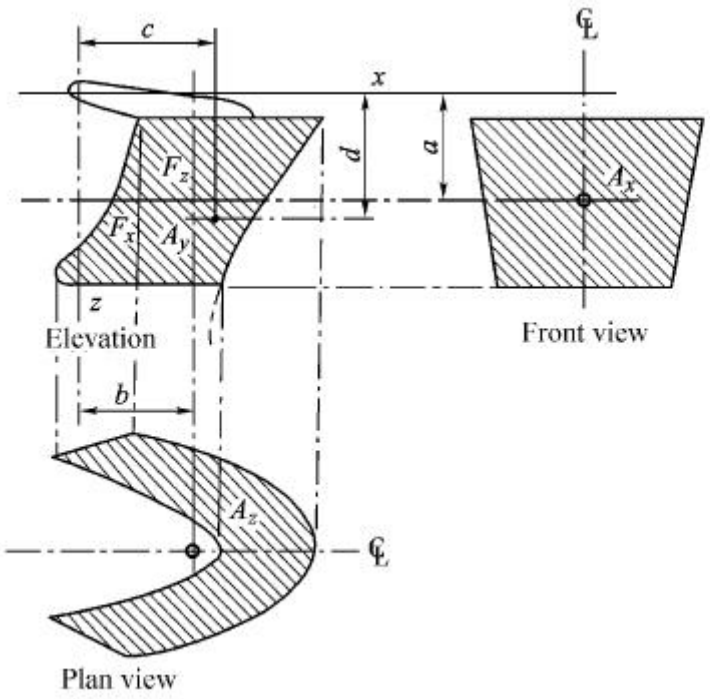



**Figure 9.4.3.1(2)**

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces are to be specially considered.

(3) For visor doors the closing moment $M_y$ under external loads, in kN·m, is to be taken as:

$$M_y = F_x a + 10Wc\ F_z b \qquad \text{kN • m}$$

where: $F_x$, $F_z$ — to be obtained in accordance with 9.4.3.1(2);

$W$ — mass of the visor door, in t;

$a$ — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);

$b$ — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 9.4.3.1(2);

$c$ — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 9.4.3.1(2).

(4) Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m$^2$ is to be taken into account.

9.4.3.2 Inner doors

(1) The design external pressure considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $p_e$, external pressure and $p_s$, hydrostatic pressure:

$$p_e = 0.45L \qquad \text{kN/m}^2$$
$$p_s = 10h \qquad \text{kN/m}^2$$

where: $L$— the ship's length, in m, but need to be taken as greater than 200 m;

$h$ — the distance, in m, from the load point to the top of the cargo space.

(2) The design internal pressure $p_i$ considered for the scantlings of securing devices of inner doors is not to be less than 25 kN/m$^2$.

### 9.4.4 Scantlings of bow doors

9.4.4.1 General requirements

(1) The strength of bow doors is to be commensurate with that of the surrounding structure.

(2) Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

9.4.4.2 Plating and stiffeners

(1) The thickness of the bow door plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.
(2) The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners.
(3) The stiffener webs are to have a net sectional area $A$ not less than:

$$A = QK/10 \quad \text{cm}^2$$

where: $Q$ — shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure $p_e$ as given in 9.4.3.1(1);
$K$ — material factor.

9.4.4.3 Primary structure
(1) The bow door stiffeners are to be supported by primary members constituting the main stiffening of the door.
(2) The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.
(3) Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in 9.4.3.1(1) of this Section and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

### 9.4.5 Scantlings of inner doors
9.4.5.1 General requirements
(1) Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 9.4.3.2(1) and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied.
(2) Where inner doors also serve as vehicle ramps, the scantlings are to comply with Section 6 of this Chapter.
(3) The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

### 9.4.6 Securing and supporting of bow doors
9.4.6.1 General requirements
(1) Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.
A means is to be provided for mechanically fixing the door in the open position.
(2) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small or flexible devices, such as cleats, intended to provide load compression of the packing material are generally not to be included in the calculations called for in 9.4.6.2(5) of this Section. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirements for redundant provision given in 9.4.6.2(6) and 9.4.6.2(7) of this Section and the available space for adequate support in the hull structure.
(3) For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment $M_y$ as given in 9.4.3.1(3) is not to be less than:

$$M_y = 10Wc + 0.1\sqrt{(a^2 + b^2)(F_x^2 + F_z^2)} \quad \text{kN} \cdot \text{m}$$

where: $F_x$, $F_z$ – to be obtained in accordance with 9.4.3.1(2);
$W$ — mass of the visor door, in t;
$a$ — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);
$b$ — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of

the visor door, as shown in Figure 9.4.3.1(2);

$c$ — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 9.4.3.1(2).

9.4.6.2 Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 9.4.2.1.

(2) For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1: $F_x$ and $F_z$;

Case 2: $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$.

(3) For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1: $F_x$,$F_y$ and $F_z$ acting on both doors;

Case 2: $0.7F_x$ and $0.7F_z$ acting on both doors and $0.7F_y$ acting on each door separately.

$F_x$,$F_y$ and $F_z$ in (2) and (3) above are determined as indicated in 9.4.3.1(2) and applied at the centroid of projected areas.

(4) The support forces as determined according to 9.4.6.2(2) and (3) (Case 1) are generally to give rise to a zero moment about the transverse axis through the centroid of the area $Ax$ (see Figure 9.4.3.1(2)). For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

(5) The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

(6) The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 9.4.2.

(7) For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 9.4.2.1. The opening moment $M_0$ to be balanced by this reaction force, is not to be taken less than:

$$M_0 = 10Wd + 5A_xa \qquad \text{kN} \bullet \text{m}$$

where: $A_x$ – to be obtained from 9.4.3.1(2) of this Section;

$W$– mass of the visor door, in t;

$a$ – vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);

$d$ – vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Figure 9.4.3.1(2).

(8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force.

$F_z$ - $10W$, in kN, within the permissible stresses given in 9.4.2.1.

where: $F_z$ – to be determined in accordance with 9.4.3.1(2);

$W$ – mass of the visor door, in t.

(9) All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

(10) For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure (see example of Figure 9.4.6.2). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose may be proposed.

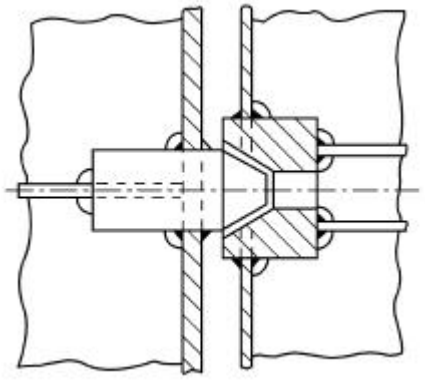


**Figure 9.4.6.2**

### 9.4.7 Securing and locking arrangements

9.4.7.1 Systems for operation

(1) Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(2) Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

① the closing and opening of the doors; and

② associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that "All securing devices are to be closed and locked before leaving harbor", is to be placed at each operating panel and is to be supplemented by warning indicator lights.

(3) Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

9.4.7.2 For indication/monitoring systems of doors, refer to relevant requirements in Section 9, Chapter 2 of PART FOUR.

### 9.4.8 Operating and maintenance manual

9.4.8.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain necessary information on:

(1) Main particulars and design drawings:

Special safety precautions;

Details of ship;

Equipment and design loading (for ramps);

Key plan of equipment (doors and ramps);

Manufacturer's recommended testing for equipment;

Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.

(2) Service conditions:

Limiting heel and trim of ship for loading/unloading;

Limiting heel and trim for door operations;

Doors/ramps operating instructions;

Doors/ramps emergency operating instructions.

(3) Maintenance:

Schedule and extent of maintenance;

Trouble shooting and acceptable clearances;

Manufacturer's maintenance procedures

(4) Register of inspections, including inspection of locking, securing and supporting devices, repairs and

renewals.
This Manual is to be submitted for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria[①].
9.4.8.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at appropriate place.

# Section 5 SIDE SHELL AND STERN DOORS

### 9.5.1 General requirements for side and stern doors

9.5.1.1 This Section applies to the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and of stern doors leading to enclosed spaces.
9.5.1.2 Stern doors for passenger ships are to be situated above the freeboard deck. Stern doors for ro-ro cargo ships and side shell doors may be either below or above the freeboard deck.
9.5.1.3 Side shell doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.
9.5.1.4 Where the sill of any side shell door is below the uppermost load line, the arrangement is to be specially considered. i.e. an inner door of equivalent strength and watertightness is to be fitted in the place. In that case leakage detection device is to be provided in the compartment between the two doors. Further, drainage of this compartment to the bilges controlled by an easily accessible screw-down valve is to be arranged.
9.5.1.5 The outer doors are to be preferably open outwards.
9.5.1.6 Definitions
(1) Securing device means a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.
(2) Supporting device and locking device, ro-ro passenger ship, ro-ro space and special category space are as defined in 9.4.1.3, Section 4 of this Chapter.

### 9.5.2 Strength criteria of side shell doors and stern doors

9.5.2.1 Scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined in 9.5.3, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K$ N/mm$^2$
Permissible shear stress $[\tau] = 80/K$ N/mm$^2$
Permissible equivalent stress $\sqrt{\sigma^2 + 3\tau^2} = 150/K$ N/mm$^2$

where: $K$ – material factor, not to be taken less than 0.72 unless a direct strength analysis with regard to relevant modes of failures is carried out.
9.5.2.2 The buckling strength of primary members is to be verified as being adequate.
9.5.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8R_{eH}$, where $R_{eH}$ is the yield strength of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.
9.5.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, with $K$ defined in 9.5.2.1 above.

### 9.5.3 Design loads of side shell doors and stern doors

9.5.3.1 The design forces, considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are not to be less than:
(1) Design forces for securing or supporting devices of doors opening inwards:

External forces: $F_e = AP_e + F_p$ kN
Internal forces: $F_i = F_o + 10W$ kN

(2) Design forces for securing or supporting devices of doors opening outwards:

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① It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the shell doors. Any damages recorded during such inspections are to be reported.

External forces: $F_e = AP_e$ kN

Internal forces: $F_i = F_0 + 10W + F_p$ kN

(3) Design forces for primary members:

External forces: $F_e = AP_e$ kN

Internal forces: $F_i = F_o + 10W$ kN

where: $A$ – area, in m$^2$, of the door opening;

$W$ – mass of door, in t;

$F_p$ – total packing force in kN; packing line pressure is normally not to be taken less than 5 N/mm;

$F_0$ – the greater of $F_c$ and $5A$, in kN;

$F_c$ – accidental force, in kN, due to loosening of cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of $F_c$ may be appropriately reduced. However, the value of $F_c$ may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes, etc.;

$P_e$ – external design pressure, in kN/m$^2$, determined at the centre of gravity of the door opening and not taken less than:

$P_e = 10(d - Z_G) + 25$ kN/m$^2$, for $Z_G < d$

$P_e = 25$ kN/m$^2$, for $Z_G \geq d$

Moreover, for stern doors of ships fitted with bow doors, $P_e$ is not to be taken less than:

$$P_e = 0.6\lambda C_H(0.8 + 0.6\sqrt{L})^2 \quad \text{kN/m}^2$$

where: $d$ – draught, in m, at the highest subdivision load line, in m;

$Z_G$ – height of the center of area of the door, in n m, above the baseline;

$\lambda$ – coefficient depending on the area where the ship is intended to be operated:

$\lambda = 1.0$ for ships intended for unrestricted service and greater coastal service;

$\lambda = 0.8$ for ships intended for coastal service;

$\lambda = 0.5$ for ships intended for sheltered water service;

$C_H$ — coefficient, to be determined as follows:

$C_H = 0.0125L$ for $L < 80$ m;

$C_H = 1$ for $L \geq 80$ m;

$L$ – ship's length, in m, but need not be taken as greater than 200 m.

### 9.5.4 Scantlings of side shell doors and stern doors

9.5.4.1 The strength of side shell doors and stern doors is to be commensurate with that of the surrounding structure.

9.5.4.2 Side shell doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

9.5.4.3 Where doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

9.5.4.4 Shell door openings are to have well-rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below and they are to comply with the relevant requirements in 2.3.7 of Section 3, Chapter 2 of this PART.

9.5.4.5 The thickness of the door plating is not to be less than the required thickness for the side shell plating, using the door stiffener spacing, but in no case less than the minimum required thickness of shell plating. Where doors serve as vehicle ramps, the plating thickness is to comply with Section 6 of this Chapter.

9.5.4.6 The section modulus of horizontal or vertical stiffeners is not to be less than that required for side framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners. Where doors serve as vehicle ramps, the stiffener scantlings are to comply with Section 6 of this Chapter.

9.5.4.7 The secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

9.5.4.8 The primary members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

9.5.4.9 Scantlings of the primary members are generally to be supported by direct strength calculations in association with the design forces given in 9.5.3.1 and permissible stresses given in 9.5.2.1. Normally, formulae for simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

### 9.5.5 Securing and supporting of doors

9.5.5.1 Side shell doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.

Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

9.5.5.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material are not generally to be included in the calculations called for in 9.5.5.4. The number of securing and supporting devices is generally to be the minimum practical whilst taking into account the requirement for redundant provision given in 9.5.5.5 and the available space for adequate support in the hull structure.

9.5.5.3 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 9.5.2.1.

9.5.5.4 The distribution of the reaction forces acting on the securing devices and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

9.5.5.5 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 9.5.2.1.

9.5.5.6 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

### 9.5.6 Securing and Locking Arrangement and Systems for operation

9.5.6.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or are to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

9.5.6.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 $m^2$ are to be provided with an arrangement for remote control, from a position above the freeboard deck, of the closing and opening of the doors and associated securing and locking devices. For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that “all securing devices are to be closed and locked before leaving harbor”, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

9.5.6.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when closed position.

9.5.6.4 For the indicating/monitoring system for doors, see relevant requirements in Section 9, Chapter 2 of PART FOUR.

### 9.5.7 Operating and Maintenance Manual

9.5.7.1 An Operating and Maintenance Manual for the side shell and stern doors is to be provided on board and is to contain necessary information on:

(1) Main particulars and design drawings:

Special safety precautions;

Details of ship;

Equipment and design loading (for ramps);

Key plan of equipment (doors and ramps);

Manufacturer’s recommended testing for equipment;

Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.

(2) Service conditions:

Limiting heel and trim of ship for loading/unloading;

Limiting heel and trim for door operations;

Doors/ramps operating instructions;

Doors/ramps emergency operating instructions.

(3) Maintenance:

Schedule and extent of maintenance;

Trouble shooting and acceptable clearances;

Manufacturer's maintenance procedures.

(4) Register of inspections and repairs, including inspection of locking, securing and supporting devices, repairs and renewals.

It is to be ensured that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria[①].

9.5.7.2 Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

# Section 6 VEHICLE RAMP

### 9.6.1 Structural strength of vehicle ramps

The relevant requirements of Section 21, Chapter 2 of this PART are to be complied with.

### 9.6.2 Framing of vehicle ramps

The strength is to be checked in accordance with the following requirements:

(1) The ramp is in a lowered position;

(2) The design vehicle load multiplied by coefficient 1.1 is the load acting on the ramp at its worst position and the mass of the ramp is also to be considered at the same time;

(3) Allowable bending stress $[\sigma] = 141/K$, N/mm$^2$, $K$ being the material factor; allowable deflection $[f] = l/200$ mm, with $l$ being the distance between the supporting points of primary structures of vehicle ramps, in mm.

### 9.6.3 Connecting hinges of vehicle ramps

The following requirements are to be complied with:

(1) The diameter $d$ of the axial pin is to comply with the following:

$$d \geq d_0$$

(2) The size of the central eye plate of hinges is to comply with the following:

$$\frac{F}{2b_0t_0} \leq [\tau], \quad b_0 \geq d_0$$

(3) The size of the eye plates on both sides of hinges is to comply with the following:

$$\frac{F}{4t_1t_2} \leq [\tau], \quad t_1 \geq d_0 / 2$$

where: $d_0$ — minimum required diameter of the axial pin, $d_0 = 0.92\sqrt{\frac{F}{[\tau]}}$ mm;

$F$— maximum force transmitted by the hinge, in N;

$t_1$, $t_2$, $b_0$, $t_0$, $d$ — size of hinge parts, in mm, see Figure 9.6.3;

$[\tau]$ — allowable shear stress, to be taken as $[\tau] = 81.6/K$, in N/mm$^2$, $K$ being the material factor.

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① It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the shell doors or stern doors. Any damage recorded during such inspections is to be reported to CCS.

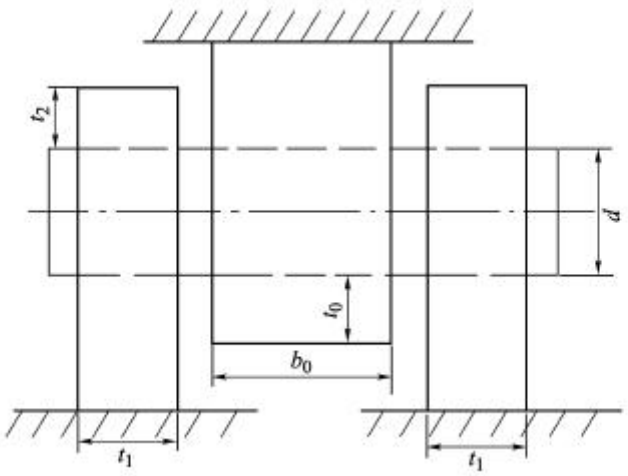



**Figure 9.6.3**

# Section 7 DIRECT CALCULATIONS

### 9.7.1 General requirements

9.7.1.1 This Section specifies the methods for direct calculations of deck transverse and girder strength of vehicle deck framing and transverse strength of hull structure.

### 9.7.2 Design load and loading conditions

9.7.2.1 For the acceleration of ship motions, see the relevant requirements of Section 5, Chapter 1 of this PART

9.7.2.2 For direct strength calculation of vehicle deck structure, the deck load is to be calculated as follows:

Vehicle load $P_h = (g + 0.5a_v)M$ kN

Uniformly distributed load $p_{d_h} = (g + 0.5a_v)p$ kN/m$^2$

Deck weight load $p_{s_h} = (g + 0.5a_v)m_s$ kN/m$^2$

where: $g$ — acceleration due to gravity, to be taken as 9.81 m/s$^2$;

$a_v$ — vertical composite acceleration, in m/s$^2$, see 9.7.2.1 of this Section;

$M$ — design vehicle mass, in t;

$p$ — design uniformly distributed load of vehicle deck, in t/m$^2$, not to be less than 0.25 t/m$^2$;

$m_s$ —deck weight, in t/m$^2$.

9.7.2.3 For direct calculation of transverse strength, the ship is assumed to heel to maximum heeling angle (if hull structures are not symmetrical to the longitudinal centerline, rolling towards portside and rolling towards starboard are to be considered separately) and the design load is to be calculated as follows:

(1) Vertical load and transverse load of vehicle deck are to be respectively calculated as follows:

Vertical load of vehicle $P_{r_v} = (g\cos\varphi_m + 0.5a_v)M$ kN

Transverse load of vehicle $P_{r_t} = (g\sin\varphi_m + 0.5a_t)M$ kN

Uniformly distributed vertical load $p_{d_r_v} = (g\cos\varphi_m + 0.5a_v)p$ kN/m$^2$

Uniformly distributed transverse load $p_{d_r_t} = (g\sin\varphi_m + 0.5a_t)p$ kN/m$^2$

Deck weight vertical load $p_{s_r_v} = (g\cos\varphi_m + 0.5a_v)m_s$ kN/m$^2$

Deck weight transverse load $p_{s_r_t} = (g\sin\varphi_m + 0.5a_t)m_s$ kN/m$^2$

where: $g$— acceleration due to gravity, to be taken as 9.81 m/s$^2$;

$\varphi_m$ —maximum heeling angle, in rad, see 9.7.2.1 of this Section, to be taken not less than 0.35 rad;

$a_v$ —vertical composite acceleration, in m/s$^2$, see 9.7.2.1 of this Section;

$a_t$ —transverse composite acceleration, in m/s$^2$, see 9.7.2.1 of this Section;

$M$ — design vehicle mass, in t;

$p$ — design uniformly distributed load of vehicle deck, in t/m$^2$, not to be less than 0.25 t/m$^2$;

$m_s$ — deck weight, in t/m$^2$.

(2) Vertical load and transverse load of superstructure deck and deckhouse deck are to be respectively calculated as follows:

Vertical load $p_{u_r_v} = (g\cos\varphi_m + 0.5a_v)m_0$ kN/m$^2$

Transverse load $p_{u_r_t} = (g\sin\varphi_m + 0.5a_t)m_0$ kN/m$^2$

where: $g$ — acceleration due to gravity, to be taken as 9.81 m/s$^2$;

$\varphi_m$ —maximum heeling angle, in rad, see 9.7.2.1 of this Section, to be taken not less than 0.35 rad;

$a_v$ —vertical composite acceleration, in m/s$^2$, see 9.7.2.1 of this Section;

$a_t$ —transverse composite acceleration, in m/s$^2$, see 9.7.2.1 of this Section;

$m_0$ — design load including deck weight, in t/m$^2$, not to be less than 0.25 t/m$^2$.

(3) The hydrostatic pressure $p_{hs}$, which is to be calculated in accordance with 1.5.3.2 of Section 5 of Chapter 1, is to be taken as the external sea pressure.

9.7.2.4 Calculation conditions are given in Tables 9.7.2.4.

**Calculations conditions** **Table 9.7.2.4**

| Condition | Load area | Direction calculations of vehicle deck strength | Direction calculations of transverse strength |
|---|---|---|---|
| 1 | Vehicle deck | Vehicle load $P_h$<br>Deck weight load $p_{s_h}$ | Vehicle vertical load $P_{r_v}$<br>Vehicle transverse load $P_{r_t}$<br>Deck weight vertical load $p_{s_r_v}$<br>Deck weight transverse load $p_{s_r_t}$ |
| | Superstructure and deckhouse | - | Vertical load $p_{u_r_v}$<br>Transverse load $p_{u_r_t}$ |
| | External | - | Hydrostatic pressure $p_{hs}$ |
| 2 | Vehicle deck | Uniformly distributed load $P_{d_h}$<br>Deck weight load $p_{s_h}$ | Uniformly distributed vertical load $p_{d_r_v}$<br>Uniformly distributed transverse load $p_{d_r_t}$<br>Deck weight vertical load $p_{s_r_v}$<br>Deck weight transverse load $p_{s_r_t}$ |
| | Superstructure and deckhouse | - | Vertical load $p_{u_r_v}$<br>Transverse load $p_{u_r_t}$ |
| | External | - | Hydrostatic pressure $p_{hs}$ |

### 9.7.3 Model and boundary conditions for strength calculation of vehicle deck structure

9.7.3.1 2- or 3-dimensional beam model or plate/beam model may be used for direct strength calculations of vehicle deck structure, and the extent of model is usually based on the following principles: Girders and transverses of the vehicle deck are to be taken as main objects of analysis, covering at least half the longitudinal length of the deck. Alternatively, a typical portion of the deck structure may be taken for modeling according to specific conditions of load distribution, deck structure and its supporting structure (e.g. pillars, bulkheads). Regardless of the length of the model, the whole tier of deck is to be considered for selection of load.

9.7.3.2 To minimize the effects of boundary constraints on the results of vehicle deck structure strength calculations, the boundary conditions are preferably to be applied at a suitable distance above and/or below the vehicle deck plane. For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero.

### 9.7.4 Model and boundary conditions for transverse strength calculation

9.7.4.1 A 2- or 3-dimensional beam or plate/beam model may be used for direct transverse strength calculations, and the extent of the model is usually based on the following principles: Primary members of the deck and their supporting structures (e.g. pillars, bulkheads, side structures and transverse webs) are to be taken as main objects of analysis, covering at least in the vertical direction all tiers of decks and their supporting structures starting from baseline to the uppermost deck, in the transverse direction the entire breadth of the ship, and in the longitudinal direction at least the length of 5 strength frame rings or one design length of a vehicle amidships, whichever is the greater.

9.7.4.2 For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero; For

intersection lines *AA′*, *BB′*, *CC′*, *DD′* of side ring frame or web frame and side shell plating, the displacement in vertical direction is to be taken as zero. For the intersection line *A′B′* of inner bottom and portside shell plating, the displacement in transverse direction is to be taken as zero. Where inner bottom is not provided, the constraint of displacement in transverse direction may be applied to the intersection line *EF* of centre keelson and bottom plating (or similar position), see Figure 9.7.4.2.

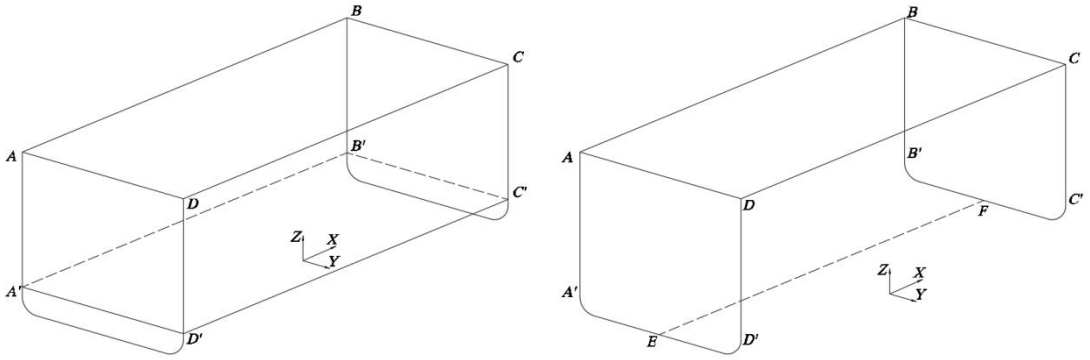



**Figure 9.7.4.2**

### 9.7.5 Permissible stress

9.7.5.1 Permissible stress for 2- or 3-dimensional beam model:

Permissible bending stress [$\sigma$] is to be:

[$\sigma$] = 165/$K$, in N/mm$^2$, for primary transverse members, [σ] may be taken as 180/$K$, in N/mm$^2$;

Permissible shear stress [τ] is to be:

[$\tau$] = 94/$K$, in N/mm$^2$;

where: $K$ – material factor;

$\sigma$– bending stress, in N/mm$^2$;

$\tau$ – shear stress, in N/mm$^2$.

9.7.5.2 Permissible stress for plate/beam model

Permissible shear stress [$\tau$] is to be:

[$\tau$] = 94/$K$, in N/mm$^2$;

Permissible equivalent stress [$\sigma_e$] is to be:

$$[\sigma_e] = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2} = 180/K \quad \text{N/mm}^2$$

where: $K$ – material factor;

$\sigma_x$ – normal stress of the element in $X$ direction under plane stress, in N/mm$^2$;

$\sigma_y$ – normal stress of the element in $Y$ direction under plane stress, in N/mm$^2$;

$\tau_{xy}$ – shear stress of the element in $X$ direction under plane stress, in N/mm$^2$.

# Section 8 EXTERNAL GLASS BALUSTRADES

### 9.8.1 General

9.8.1.1 The requirements of this Section apply solely to external glass balustrades. External glass balustrades are barriers constructed with glass that are used on exposed decks.

9.8.1.2 Glass balustrades, in lieu of bulwark or guard rails (see Section 19, Chapter 2 of this PART), may be accepted on exposed decks above position 2 specified in 1.1.2.22, Section 1, Chapter 1 of this PART, except on mooring deck and in way of lifeboats and life rafts and embarkation stations.

9.8.1.3 Glass is to be manufactured in accordance with a recognised National or International Standard.

9.8.1.4 The detailed arrangement, applicable loads and structural strength calculations are to be submitted to CCS.

### 9.8.2 Arrangement requirements

9.8.2.1 External glass balustrades are to be not less than 1 m in height.

9.8.2.2 In general, openings (e.g. the gaps between panels or the gap between the deck and the bottom of a panel) are not to be greater than 76 mm unless required for water freeing.

9.8.2.3 If a well is formed, the necessary drainage port is to be provided. Openings for water freeing are not to be greater than 230 mm.

**9.8.3 Design pressure**

9.8.3.1 For the lowest weather deck, the minimum design pressure $P_w$ of glass balustrades is to be calculated as follows:

$$P_w=9.81h, \text{ kN/m}^2$$

where: $h$——head in 2.17.2, Section 17, Chapter 2 of this PART.

9.8.3.2 For higher exposed decks, the minimum design pressure $P_w$ of glass balustrades is to be calculated as follows:

(1) Below $1.7C$ m above the scantling draught, $P_w$=5kN/m$^2$, where $C$ is the coefficient as specified in 2.2.3.1, Section 2, Chapter 2 of this PART;

(2) For other locations, $P_w$=2.5kN/m$^2$.

**9.8.4 Minimum scantling requirements**

9.8.4.1 External glass balustrades using monolithic glass are to comply with the following requirements:

(1) Minimum thickness of glass is not to be less than 6.0 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm$^3$;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm$^3$.

9.8.4.2 External glass balustrades using laminated glass are to comply with the following requirements:

(1) Minimum thickness for each glass pane is not to be less than 4 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm$^3$;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm$^3$.

9.8.4.3 The section modulus requirements in 9.8.4.1 and 9.8.4.2 above are based on steel. For other metallic materials, equivalent section modulus is to be calculated.

9.8.4.4 The glass panes are to be supported at minimum two opposite sides by metallic mounting frames. The glass panes can be fixed to the metal frame by mechanical means or adhesive. If the metal mounting frames are connected to the stanchion by bolts, there is to be no less than two force bolts on one side.

9.8.4.5 The overlap between the glass panes and metallic frames is not to be less than 10 mm or $b$/75 mm, whichever is greater, but not more than 20 mm, $b$ is the breadth of the glass pane, in mm.

9.8.4.6 In public areas, laminated glass panes are required for external glass balustrades.

**9.8.5 Glass thickness**

9.8.5.1 For monolithic toughened glass, the thickness is to be less than the value obtained from the following formula:

$$t = b\sqrt{\beta P} \,/\, 200 \quad \text{mm}$$

where: $b$ ——length of the shorter side of the glass, in mm;

$P$ ——load for calculation, $P = 0.5Pw$, in kN/m$^2$;

$P_w$——design pressure, in kN/m$^2$, see 9.8.3 of this Section;

$\beta$ ——coefficient, to be taken as follows:

1) glass with firm support on all sides:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \quad \text{for} \quad A_R \le 3.6$$

$$\beta = 0.7645 \quad \text{for} \quad A_R > 3.6$$

2) glass with firm support on two sides only:

$$\beta = 0.7645$$

where: $A_R$ ——aspect ratio of rectangle window, to be taken as follows

$$A_R = a / b$$

$a$ ——length of the longer side of the glass, in mm;

$b$ ——length of the shorter side of the glass, in mm.

9.8.5.2 For laminated toughened glass, the equivalent thickness is to be less than the value obtained from 9.8.5.1. The equivalent thickness is calculated according to the following formula:

$$t_e = \sqrt{\sum_{i=1}^{n} t_i^2} \quad \text{mm}$$

where: $n$ —number of glass layers;

$t_i$ —thickness of the i$^{th}$ layer glass.

### 9.8.6 Balustrade stanchions

9.8.6.1 For balustrade stanchions below 1.7$C$ m above the scantling draught, the section modulus $W$ at the bottom is not to be less than:

$$W = 655\frac{\mathrm{P\,Sl^2}}{\mathrm{R_{eH}}} \quad \mathrm{cm^3}$$

where: $S$ ——distance between stanchions, in m;

$l$ ——height of the stanchion, in m;

$P$ ——load for calculation, $P = Pw$, in kN/m$^2$;

$P_w$——design pressure, in kN/m$^2$, see 9.8.3 of this Section;

$R_{eH}$——yield stress of material, in N/mm$^2$.

9.8.6.2 For balustrade stanchions below 1.7$C$ m above the scantling draught, the shear area $A$ at the bottom is not to be less than:

$$A = 22.7\frac{\mathrm{P\,Sl}}{\mathrm{R_{eH}}} \quad \mathrm{cm^2}$$

where: $S$ ——distance between stanchions, in m;

$l$ ——height of the stanchion, in m;

$P$ ——load for calculation, $P = Pw$, in kN/m$^2$;

$R_{eH}$——yield stress of material, in N/mm$^2$.

# CHAPTER 10 TUGS

## Section 1 GENERAL PROVISIONS

### 10.1.1 Application

10.1.1.1 The provisions of this Chapter apply to ships intended specially for towing.

10.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

10.1.1.3 For the determination of scantlings of tugs, the draught $d$ used is not to be less than 85% of the mounded depth.

10.1.1.4 For the calculation of rudder force, the design speed $V$ of ship is not to be taken as less than 10 kn.

### 10.1.2 Plans and documents

10.1.2.1 In addition to those specified in Section 1, Chapter 2 of this PART, the following plans are to be submitted for approval:

(1) Supporting structure of towing equipment (appropriate strength calculations are submitted for information).

(2) Towing arrangement.

(3) Fender (structure) arrangement.

## Section 2 HULL FRAMING

### 10.2.1 Web beam

10.2.1.1 A web beam is to be arranged throughout in way of the mid-portion of the long opening for machinery space.

### 10.2.2 Side strengthening abaft the fore peak

10.2.2.1 Where the side is framed transversely, the side framing abaft the fore peak is to be strengthened in compliance with the requirements of 2.15.2 of this PART to an extent to 0.3$L$ from the F.P. Within the region of strengthening, the section moduli of main and 'tween deck frames are to be 20% greater than those required in Section 7, Chapter 2 of this PART.

## Section 3 MACHINERY CASINGS

### 10.3.1 Machinery casings

10.3.1.1 The height of exposed machinery casings is not to be less than 900 mm. The stiffeners of the casings are to be spaced not more than 750 mm apart. The thickness of casing wall is to be increased by 20% over that required in 2.17.9.3 of this PART. But the section modulus of the stiffeners is to be increased by 50 % over that required in 2.17.9.3 of this PART.

## Section 4 BULWARKS AND FENDERS

### 10.4.1 Bulwarks

10.4.1.1 Tugs are to be provided with tumblehome bulwarks and the thickness $t$ of bulwark plating is to comply with the following requirements:

$t$ = 5 mm for $L \leq 30$ m;

$t$ = 6 mm for $30 < L < 50$ m;

$t$ = 7 mm for $L \geq 50$ m.

where: $L$ – length of ship, in m.

10.4.1.2 The bulwarks are to be supported by stays with a flange or face plate. The stays are to be spaced not more than two frame spaces apart and are to be in line with the beams.

### 10.4.2 Fenders

10.4.2.1 Fenders are to be fitted along the deck line at side over the full length of tugs and are to have a

thickness equal to that of side shell plating at 0.4*L* amidships. Stiffening brackets are to be arranged inside the fenders.

# Section 5 TOWING ARRANGEMENTS AND SUPPORTING STRUCTURE

### 10.5.1 Towing hooks and towing winches

10.5.1.1 Towing hooks or the position of fixed towing guide point are normally to be situated at 5% to 10% of the ship's length abaft amidships, but in no case are they to be sited forward of the longitudinal centre of gravity of the tug in any anticipated condition of loading. In addition, they are to be located as low as practicable in order to minimize heeling moments arising in normal working conditions.

10.5.1.2 Towing winches and its members are to undertake the breaking loads of the towline selected by the tug and without permanent deformation. Towing hooks are to undertake the testing loads and without permanent deformation. The breaking loads of towlines and the testing loads of towing hooks may be determined according to CCS Guidelines for Towage at Sea.

### 10.5.2 Releasing arrangements

10.5.2.1 Towing hooks are to have reliable ship arrangements which facilitate towline releasing regardless of the direction of the towing line or the angle of heel and can avoid any inadvertent slipping.

10.5.2.2 The operating position of the slip arrangements is to be so sited as to ensure free visibility of the towing hook. It is recommended that the arrangements also be operable from the bridge.

### 10.5.3 Foundations

10.5.3.1 Pillars or pillar bulkheads are to be provided as far as possible under towing arrangements.

10.5.3.2 The design load for the supporting structure in way of towing arrangements is not to be less than the breaking loads of the towline selected by the tug.

10.5.3.3 The primary members of foundations are to be determined by direct calculation, and their allowable stress is as follows:

Allowable shear stress: $[\tau] = 87/K$ N/mm²;

Allowable bending stress: $[\sigma] = 150/K$ N/mm²;

Allowable equivalent stress: $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 213/K$ N/mm²

where: $K$ — material factor.

# Section 6 TOWING WINCH EMERGENCY RELEASE SYSTEMS

### 10.6.1 Scope and definitions

10.6.1.1 This Section defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, including those ships normally not intended for towing operation in transverse direction.

10.6.1.2 This Section is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

10.6.1.3 This Section applies to ships contracted for construction on or after 1 January 2020.

10.6.1.4 The purpose of this section is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize, see Figure 10.6.1.4.

10.6.1.5 For the purposes of this Section, definitions are as follows:

(1) Emergency release system refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.

(2) Maximum design load is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).

(3) Fleet angle is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 10.6.1.5.

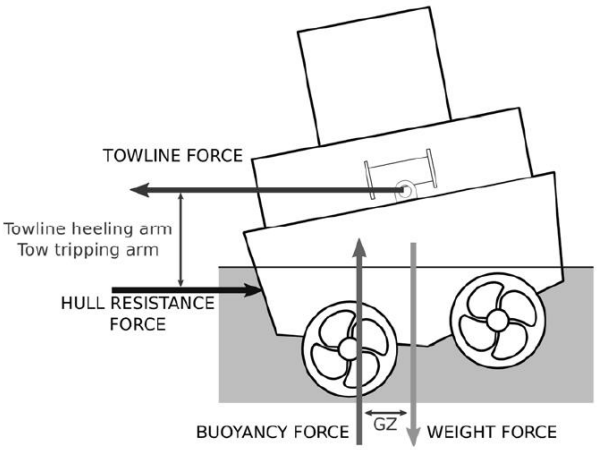



**Figure 10.6.1.4 Forces during towing**

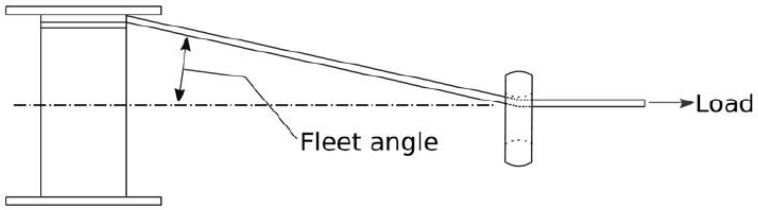



**Figure 10.6.1.5 Towline fleet angle**

**10.6.2 General requirements**

10.6.2.1 The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

10.6.2.2 All towing winches are to be fitted with an emergency release system.

**10.6.3 Performance requirements for emergency release system**

10.6.3.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

10.6.3.2 The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

10.6.3.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

10.6.3.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

10.6.3.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

(1) the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or

(2) 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

10.6.3.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with 10.6.3.7.

10.6.3.7 The alternative source of energy required by 10.6.3.6 of this Section is to be sufficient to achieve the most onerous of the following conditions (as applicable):

(1) sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three

activations of the most demanding winch connected to it.
(2) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power) sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in 10.6.3.5 if this is less than five minutes.

**10.6.4 Operational requirements for emergency release system**

10.6.4.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as safe location, unless it is documented that the position is at least protected against towline break or winch failure.

10.6.4.2 The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

10.6.4.3 The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

10.6.4.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

10.6.4.5 Controls for emergency use are to be protected against accidental use.

10.6.4.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

10.6.4.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

10.6.4.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of Section 6, Chapter 2 of PART SEVEN of the Rules.

10.6.4.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

10.6.4.10 The annual survey method for winch is to be recorded.

**10.6.5 Test requirements for emergency release system**

10.6.5.1 General requirements

(1) All testing defined within this Section is to be witnessed by a surveyor.

(2) For each emergency release system or type thereof, the performance requirements of 10.6.3 of this Section are to be verified either at the manufacturer’s works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement.

(3) The performance capabilities, as well as instructions for operation of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

(4) Instructions for surveys of the emergency release system are to be documented by the manufacturer, when agreed, and made available on board the ship on which the winch has been installed.

(5) Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.

10.6.5.2 Installation trials

(1) The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

(2) Where the performance of the winch in accordance with 10.6.3 of this Section has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

# CHAPTER 11 OFFSHORE SUPPLY SHIPS

## Section 1 GENERAL PROVISIONS

### 11.1.1 Application

11.1.1.1 This Chapter applies to offshore supply ships specially designed and constructed for the carriage of specialized stores and cargoes to mobile offshore units or fixed offshore installations, and also applies to offshore tug/supply ships or offshore anchoring handling/tug/supply ships.

11.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

11.1.1.3 This Chapter applies to supply ships having the accommodation and bridge erections in the forward part of the vessel and an exposed deck in the after part for the handling of cargo at sea.

11.1.1.4 In addition to the requirements of this Chapter, tug/supply ships are to comply with the relevant requirements as specified in Section 5, Chapter 10 of this PART. A tug/supply ship, when engaged in towing operations, is in general not to carry deck cargo.

### 11.1.2 Plans and documents

11.1.2.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans covering the following items are to be submitted for approval:

(1) Independent cargo tanks and their foundations and securing arrangements;

(2) Drawing of the deck(s) showing the details of loads, the points where they apply and lashing arrangement;

(3) Towing arrangement;

(4) Supports and foundations for towing winches, stern towing bollards and for stern rollers of anchor handling/supply ships (appropriate strength calculations are submitted for information);

(5) Movable decks, including the stowing arrangements for portable components;

(6) Freeing arrangement;

(7) Fender arrangement (structure).

## Section 2 CARGO CONTAINMENT AND OTHER FITTINGS

### 11.2.1 Cargo containment

11.2.1.1 Means are to be provided to enable deck cargoes to be adequately secured and protected. In general, suitable inner bulwarks, rails, bins or storage racks of substantial construction are to be provided and properly secured to adequately strengthened parts of the hull structure.

11.2.1.2 Properly designed locking equipment or efficient means for lashing the deck cargoes are to be fitted where appropriate.

11.2.1.3 Small hatches (including escape hatches), control valves, ventilators, air pipes, etc., are to be situated clear of the cargo containment areas and are to be fitted in protected positions.

### 11.2.2 Doors and accesses

11.2.2.1 If possible, the accesses to machinery spaces are to be arranged in forecastle. Any accesses to machinery spaces from weather cargo decks are to be provided with two weathertight closing appliances. The accesses to spaces below the weather cargo decks are to be preferably from a position on or above the superstructure deck as far as possible.

11.2.2.2 Hatches, doors, etc. which give access to the exposed cargo deck are to be kept closed during navigation, and are to be clearly marked to indicate that these fittings are to be kept closed except for access.

### 11.2.3 Side scuttles, windows and skylights

11.2.3.1 Side scuttles, windows and skylights are to comply with the relevant requirements of Section 8, Chapter 1 of this PART.

11.2.3.2 Windows are only allowed to be fitted in the following locations and side scuttles are to be fitted in other positions. See Figure 11.2.3.2.

(1) Second tier and higher above the freeboard deck:

① in the aft end bulkheads of deckhouses and superstructures;

② in the sides of deckhouses and superstructures which are not part of the shell plating;

(2) Third tier and higher above the freeboard deck:

① in the forward facing bulkheads of deckhouse and superstructures, except that in the first tier of the front bulkhead above the weather deck, only side scuttles will be accepted.

11.2.3.3 Permanently attached deadlights are to be provided as follows:

(1) Side scuttles:

① in the side shell plating;

② in the forward facing bulkheads of superstructures and deckhouses;

③ in the sides of deckhouses and superstructures up to and including the third tier above the freeboard deck;

④ in the after end bulkheads of superstructures, deckhouses, casings and companionways in the first and second tiers above the freeboard deck.

(2) Windows:

① in the sides of deckhouses and superstructures in the second and third tiers above the freeboard deck;

② in the after end bulkheads of superstructures, deckhouses, casings and companionways in the second tier above the freeboard deck.

11.2.3.4 On windows in the second tier and higher above the freeboard deck, hinged storm covers may be fitted in lieu of deadlights, provided there is safe access for closing.

11.2.3.5 Windows in the wheelhouse front are to have deadlights or storm covers. For storm covers, an arrangement for easy and safe access is to be provided, (e.g. gangway with railing). However, for practical purposes, the deadlights or storm covers may be portable if stowed adjacent to the window for quick fitting. At least two of the deadlights or storm covers are to have the means of providing a clear view.

11.2.3.6 Deadlights for side scuttles, and for windows not mentioned in 11.2.3.4 and 11.2.3.5, are to be internally hinged.

11.2.3.7 The thickness of toughened glass for windows is not to be less than the value calculated by the following formula, and the minimum is not to be less than 10 mm.

$$t = b\sqrt{\varphi\beta\eta h} \qquad \text{mm}$$

where:

$\varphi$ — coefficient, taken as 2 for fronts, 1.2 for sides and aft ends;

$\eta$ — coefficient, taken as 223 for fronts and sides on the forth tier or above, 125 for aft ends on the forth tier or above, 500 for other cases;

$h$ — design head of window, calculated according to 2.17.2, Chapter 2 of this PART;

$\beta$ — coefficient, to be calculated by the following:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \quad \text{for} \quad A_R \le 3.6$$

$$\beta = 0.7645, \quad \text{for} \quad A_R > 3.6$$

where: $A_R$ —aspect ratio factor of window, calculated by the following equation:

$$A_R = a/b$$

$a$ — length of long edge of window, in m;

$b$ — length of short edge of window, in m.

11.2.3.8 Skylights, where fitted, are to be of substantial construction. The height of coamings of skylights is not to be less than 600 mm when situated on open freeboard decks, and raised quarter decks and open superstructure decks forward of 1/4$L$ from F.P., and 450 mm when situated on open superstructure decks abaft of 1/4$L$ from F.P. The thickness of glass in skylights is to be equal to that required for side scuttles or windows at the same position. Skylights are to be provided with strong storm covers.

11.2.3.9 For laminated toughened glass, the equivalent thickness is not to be less than that calculated according to 11.2.3.7. The equivalent thickness is to be calculated by the following formula and the thickness of single layer of glass is not to be less than 4 mm.

$$t_e = \sqrt{\sum_{i=1}^{n} t_i^2}$$

where: $n$ — the number of layer of glass;

$t_i$ — the thickness of the i$^{th}$ layer of glass.

### 11.2.4 Air pipes, ventilators and freeing ports

11.2.4.1 Air pipes situated on the exposed cargo and forecastle decks are to be provided with automatic closing devices.
11.2.4.2 Machinery space ventilators are to be arranged above the superstructure deck, or above an equivalent level if no superstructure deck is fitted.
11.2.4.3 The area of the freeing ports in the side bulwarks on the cargo deck is to be suitably increased above that required in 1.8.6.2, Chapter 1 of this PART. The disposition of the freeing ports is to be carefully considered to ensure the most effective drainage of water trapped in deck cargoes or in recesses in the after end bulkhead of the forecastle.
In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the freeing ports.
11.2.4.4 Engine exhaust outlets are to be located as high as practicable above the deck and are to be fitted with spark arresters.

# Section 3 SHELL AND DECK PLATING

### 11.3.1 Shell plating

11.3.1.1 The thickness of side shell is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART, but is in no case to be less than 9 mm.
11.3.1.2 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas of anchor handling/supply ships is to be suitably reinforced.

### 11.3.2 Decks

11.3.2.1 The minimum thickness $t$ of deck plating is not to be less than that obtained from the following formula:

$$t = 0.025L + 7 \quad \text{mm}$$

where: $L$ — length of ship, in m.
In the deck cargo area, the thickness $t$ of deck plating is, in addition, in no case to be less than that obtained from the following formula:

$$t = 4.8s\sqrt{hK} \quad + 2.5 \quad \text{mm}$$

where: $s$ — spacing of beams or longitudinals, in m;
$h$ — design head, in m, to be determined from $h = 0.14p$ ($p$ being the load of deck, in kPa), but not to be less than 3.5 m;
$K$ — material factor.
11.3.2.2 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness.

# Section 4 HULL ENVELOPE FRAMING

### 11.4.1 Deck framing

11.4.1.1 The scantlings of cargo decks are to be suitable for the specified loadings, but in no case is a head less than 3.5 m to be used.
11.4.1.2 Additional local increases in scantlings is to be required where specialized cargoes are likely to induce concentrated loads.

### 11.4.2 Side framing

11.4.2.1 Efficient fenders are to be fitted to the ship's side above the waterline, and are to have a thickness equal to that of side shell. Stiffeners are to be arranged inside the fenders. If fenders are not provided, the thickness of the shell plating at least 600 mm below the deck is to be increased by 5 mm.
11.4.2.2 The section moduli of the main and 'tween deck frames are to be 25% greater than those required in Section 7 of Chapter 2 of this PART. Frames are not to be scalloped.

### 11.4.3 Bottom framing

11.4.3.1 The flanges of bottom in way of stern is to be efficiently stiffened.

# Section 5 SUPERSTRUCTURES AND DECKHOUSES

### 11.5.1 Scantlings

11.5.1.1 The section modulus of the frames in superstructures is to be 25% greater than those required in Section 7, Chapter 2 of this PART. And the scantlings of the end bulkheads of superstructures are not to be less than those as specified in Table 11.5.1.2 of this Section.

11.5.1.2 The scantlings of deckhouses situated on the forecastle deck and above are to comply with the requirements of Table 11.5.1.2.

**Plate thickness, Stiffener Modulus and Depth of Deckhouses Table 11.5.1.2**

| Position | Thickness $t$ of plating (mm) | Section modulus $W$ of stiffeners ($cm^3$) | Depth of stiffeners |
|---|---|---|---|
| Fronts | The greater of $12s$ or 8.0 | $34sl^2$ | Not less than 100 |
| Sides | The greater of $10s$ or 6.5 | $27sl^2$ | Not less than 75 |
| Aft ends | The greater of $8s$ or 6.5 | $27sl^2$ | Not less than 65 |

Note: $s$ and $l$ are respectively spacing and span of stiffeners, in m.

### 11.5.2 End connection

11.5.2.1 Both ends of the stiffeners in superstructures and deckhouses are to be bracketed or connected by other effective means on all tiers.

# CHAPTER 12 BARGES

## Section 1 GENERAL PROVISIONS

### 12.1.1 Application

12.1.1.1 The barges defined in this Chapter are non-self-propelled ships pushed or towed by other ships and divided into the following types:

(1) Barges carrying general dry cargo in cargo holds;

(2) Barges carrying cargo oil in cargo tanks;

(3) Shipborne barges carrying general dry cargo in cargo holds and carried on board a barge carrier;

(4) Specially designed pontoons for the carriage of cargo on deck;

(5) Barges dedicated to transporting marine engineering jacket structure and landing jacket into water by the stern for launching of jacket;

(6) Barges carrying chemicals in cargo tanks;

(7) Barges carrying liquefied gas in cargo tanks.

12.1.1.2 Where not covered by this Chapter, barges carrying cargo oil in bulk in cargo tanks are to comply with the relevant requirements of Chapter 5 or 6 of this PART according to its structural configuration; barges carrying chemicals in cargo tanks are to comply with the relevant requirements of Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk; barges carrying liquefied gas in cargo tanks are to comply with the relevant requirements of Appendices 1 and 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk and other barges are to comply with the relevant requirements of Chapter 2 of this PART.

12.1.1.3 For pontoons regarded as one of offshore floating facilities, the structure may be in accordance with the requirements of this Chapter for pontoon barges.

### 12.1.2 Plans and documents

12.1.2.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans and documents covering the following are to be submitted for approval:

(1) Details of structure and fittings to which deck cargo securing lashings, etc. are attached;

(2) Details of bollards and their supporting structure;

(3) Where pusher tugs or integral tug/barge systems are proposed, full details and data of the attachment and support arrangements;

(4) Longitudinal strength (appropriate strength calculations are submitted for information) and lifting arrangements for shipborne barges.

### 12.1.3 Structural configuration

12.1.3.1 For barges with large deck openings, deck and bottom are in general to be longitudinally framed.

12.1.3.2 Barges are to be fitted with a collision bulkhead extending intact to the strength/weather deck and, in general, this is to be located in accordance with Table 12.1.3.2. Greater distance between the collision bulkhead and the forward perpendicular may be accepted if assessed by damage stability calculation.

**Table 12.1.3.2**

| Length $L$ of ship (m) | Distance between collision bulkhead and forward perpendicular (m) | |
|---|---|---|
| | Minimum | Maximum |
| ≤ 150 | 0.05$L$ | 0.05$L$ + 4.5 |
| > 150 | 0.05$L$ or 10, whichever is the lesser | 0.08$L$ |

12.1.3.3 Where the ends of the barge are identical both in structural arrangement and in shape so that its fore and after ends are not distinguishable, collision bulkheads are to be fitted at both ends.

12.1.3.4 Pusher barges are in general to be fitted with a collision bulkhead at the aft end.

12.1.3.5 The total number of watertight bulkheads is in general not to be less than required in Table 12.1.3.5. For ships of over 190 m in length, this is to be determined by direct calculation. Attention is to be paid to reasonable and even arrangement of transverse watertight bulkheads.

**Total Number of Transverse Watertight Bulkheads** **Table 12.1.3.5**

| Length $L$ (m) | $L \leq 60$ | $60 < L \leq 85$ | $85 < L \leq 105$ | $105 < L \leq 145$ | $145 < L \leq 165$ | $165 < L \leq 190$ |
|---|---|---|---|---|---|---|

| Length $L$ (m) | $L \leq 60$ | $60 < L \leq 85$ | $85 < L \leq 105$ | $105 < L \leq 145$ | $145 < L \leq 165$ | $165 < L \leq 190$ |
|---|---|---|---|---|---|---|
| Total number of watertight bulkheads | 3 | 4 | 5 | 6 | 7 | 8 |

12.1.3.6 Pontoon barges are in general to be fitted with longitudinal bulkheads extending fore and aft in accordance with Table 12.1.3.6, the scantlings of which are to be calculated as required for watertight longitudinal bulkheads. Attention is to be paid to reasonable arrangement of longitudinal bulkheads. For pontoon barges with $B/D$ greater than 6, this is to be determined by direct calculation.

**Total Number of Longitudinal Bulkheads** **Table 12.1.3.6**

| $B/D$ | $B/D \leq 2.5$ | $2.5 < B/D \leq 3$ | $3 < B/D \leq 4$ | $4 < B/D \leq 5$ | $5 < B/D \leq 6$ |
|---|---|---|---|---|---|
| Total number of longitudinal bulkheads | 0 | 1 | 2 | 3① | 3 |

Note: ① Centre longitudinal bulkheads may be replaced by longitudinal trusses.

12.1.3.7 For pontoon barges with $B/D$ equal to or greater than 3, the transverse strength is to be checked by direct calculation (see Appendix of this Chapter).

# Section 2 LONGITUDINAL STRENGTH

### 12.2.1 General requirements

12.2.1.1 The longitudinal strength of barges is to comply with the relevant requirements of Section 2, Chapter 2 of this PART, with the exception of the requirements for loading instruments.

12.2.1.2 For shipborne barges intended to be lifted on board by crane, longitudinal strength calculations for a condition "fully loaded barge suspended by crane" are to be made with the following permissible stresses:

Permissible bending stress $[\sigma] = 150/K$ N/mm²

Permissible shear stress $[\tau] = 100/K$ N/mm²

where: $K$ — material factor.

12.2.1.3 For barges having large deck openings, torsional strength is to be checked in accordance with Chapter 7 of this PART.

12.2.1.4 Where the transverse watertight bulkheads and longitudinal bulkheads of pontoon barges are fitted in compliance with the requirements for structural arrangement in Section 1 of this Chapter, their proportions may exceed those specified in 2.2.1.2 of Section 2, Chapter 2 of this PART when the requirements for longitudinal strength in Section 2, Chapter 2 of this PART are applied, provided that the following condition is met:

$$L/B > 3$$
$$B/D \leq 6.0$$

12.2.1.5 For pontoon barges not meeting the condition in 12.2.1.4 above, this is generally to be determined by direct calculation. See 2.2.9 of Chapter 2 for direct calculation of wave loads.

# Section 3 SHELL AND DECK PLATING

### 12.3.1 General requirements

12.3.1.1 In addition to the requirements of this Section, the shell and deck plating of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 6 of this PART and those of other barges are to comply with the relevant requirements of Chapter 2 of this PART.

### 12.3.2 Shell plating Decks

12.3.2.1 On barges with two chines each side, the thickness of bilge plating is to be calculated from the bottom plating formulae. On hard chine barges, flanged chines will not, in general, be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is not to be less than 3 times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

12.3.2.2 For barges of less than 100 m in length and without dead rise, the thickness of plate keel is to be calculated from the bottom plating formulae.

### 12.3.3 Decks

12.3.3.1 For barges with large deck openings, the half sectional area $a$ of the strength deck within 0.4$L$ amidships is not to be less than that obtained from the following formula:

$$a = \frac{1}{4.3} B(L + 30) \quad \text{cm}^2$$

where: $L$ — length of ship, in m;
$B$ — breadth of ship, in m.

The half sectional area of deck means the sum of sectional areas of the continuous longitudinal members outside the line of openings and on one side of the longitudinal centreline, such as deck plating, deck longitudinals and deck girders.

12.3.3.2 For pontoons, the thickness of deck plating in the deck cargo area is, in addition, not to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \quad \text{mm, but not less than 6 mm}$$

where: $s$ — spacing of beams or longitudinals, in m;
$h$ — design head, in m, to be taken as $0.14p + 0.3$, $p$ being the design load, in kPa;
$K$ — material factor.

12.3.3.3 Where vehicles are to be carried on deck, the deck plating is also to comply with the relevant requirements of Section 21, Chapter 2 of this PART.

## Section 4 HULL ENVELOPE FRAMING

### 12.4.1 General requirements

12.4.1.1 The hull envelope framing of barges carrying dry cargo in cargo holds are to comply with the relevant requirements of Chapter 2 of this PART. The hull envelope framing of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 6 of this PART. The hull envelope framing of pontoon barges are to comply with the relevant requirements of this Section.

12.4.1.2 In way of deck and bottom primary transverse members, a web frame is to be fitted so that the bottom, side and deck transverses are connected into a transverse ring system to ensure sufficient transverse strength.

12.4.1.3 Pontoon barges are in general longitudinally framed. If they are framed transversely, transverse ring systems or transverse trusses are to be suitably fitted to ensure sufficient transverse strength.

12.4.1.4 Figure 12.4.1.4 shows the longitudinally framed structure of pontoon barges.

12.4.1.5 Figure 12.4.1.5 shows the transversely framed structure of pontoon barges.

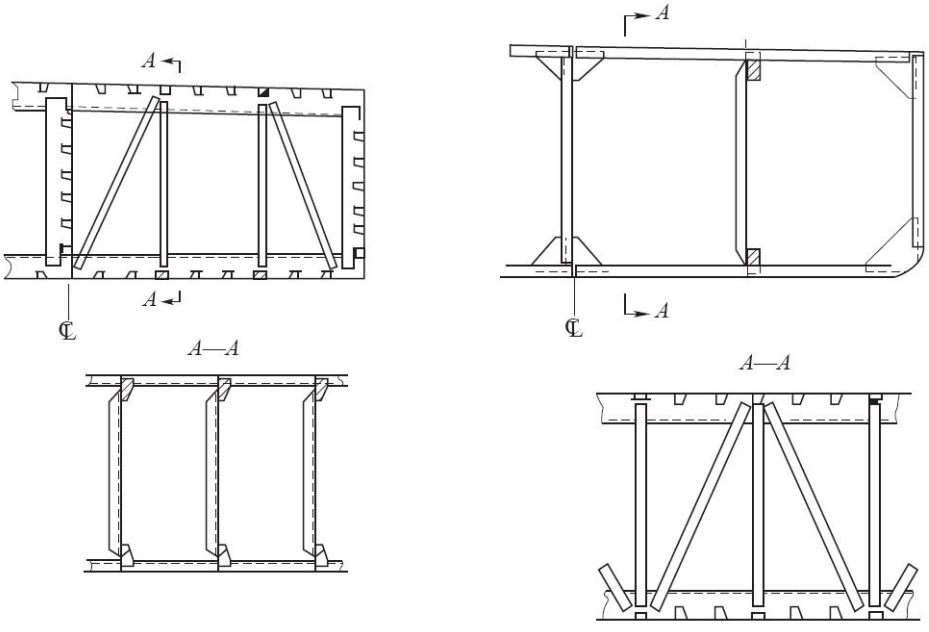


**Figure 12.4.1.4** **Figure 12.4.1.5**

### 12.4.2 Bottom framing of pontoons

12.4.2.1 Where transversely framed, bottom frames are to be fitted at every frame, and their section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 9.5sDl^2K \quad \text{cm}^3$$

where: $s$ — spacing of bottom frames, in m;
$D$ — moulded depth, in m;
$l$ — span of bottom frames, in m; supporting structures of bottom frames are to be ship side, longitudinal bulkheads or bottom stringers;
$K$ — material factor.

12.4.2.2 Where longitudinally framed, the section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = CsDl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$D$ — moulded depth, in m;
$l$ — span of longitudinal, in m; supporting structures of bottom longitudinals are to be transverse bulkheads or bottom webs;
$C$ — coefficient, taken as:
$C = 12$, for rake-ended bow of pontoon barges;
$C = 10.5$, for others;
$K$ — material factor.

12.4.2.3 The section modulus $W$ of bottom stringers (including bottom chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 9.5SDl^2K \quad \text{cm}^3$$

where: $S$ — average width of areas supported by bottom stringers, in m;
$D$ — moulded depth, in m;
$l$ — span of bottom stringers, in m; supporting structures of bottom stringers are to be transverse bulkheads, truss pillars;
$K$ — material factor.

12.4.2.4 The section modulus $W$ of bottom webs (including bottom chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = CSDl^2K \quad \text{cm}^3$$

where: $S$ — average width of areas supported by bottom webs, in m;
$D$ — moulded depth, in m;
$l$ — span of bottom web, in m; supporting structures of bottom webs are to be ship side, longitudinal bulkheads or truss pillars;
$C$ — coefficient, taken as:
$C = 11$, for rake-ended bow of pontoon barges;
$C = 9.5$, for others;
$K$ — material factor.

12.4.2.5 Primary bottom members (bottom stringers and webs) are to comply with the following requirements:

(1) The web depth $h$ of primary members is not to be less than 2 times the depth of the slot for the passage of secondary members (bottom frames and longitudinals), and not to be less than that obtained from the following formula:

$$h = 125l \quad \text{mm}$$

where: $l$ — span of primary member, in m.

(2) The web thickness $t$ of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \quad \text{mm, not less than 7 mm}$$

where: $h$ — web depth of primary member, in mm.

### 12.4.3 Side framing of pontoons

12.4.3.1 The section modulus $W$ of frames is not to be less than that obtained from the following formula:

$$W = 9.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of frames, in m;
$l$ — span of frame, in m;
$h$ — head taken in calculation, in m; vertical distance measured from the midpoint of span of the frame to deck at side, but not to be less than $0.01L + 0.7$ m, $L$ being length of ship, in m;

$K$ — material factor.

12.4.3.2 The section modulus $W$ of side longitudinals is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$l$ — span of longitudinal, in m;

$h$ — head taken in calculation, in m; vertical distance measured from the side longitudinal to deck at side, but not to be less than $0.01L + 0.7$ m, $L$ being length of ship, in m;

$C$ — coefficient, taken as:

$C = 9.0$, for rake-ended bow of pontoon barges;

$C = 8.0$, for others;

$K$ — material factor.

12.4.3.3 The section modulus $W$ of longitudinally framed web frames is not to be less than that obtained from the following formula:

$$W = CShl^2K \quad \text{cm}^3$$

where: $S$ — spacing of web frames, in m;

$l$ — span of web frame, in m;

$h$ — head taken in calculation, in m; vertical distance measured from the midpoint of span of the web frame to deck at side, but not to be less than $0.01L + 0.7$ m, $L$ being length of ship, in m;

$C$ — coefficient, taken as:

$C = 9.5$, for rake-ended bow of pontoon barges;

$C = 8.5$, for others;

$K$ — material factor.

12.4.3.4 Longitudinally framed web frames are to comply with the relevant requirements of 12.4.2.5 of this Section.

**12.4.4 Deck framing of pontoons**

12.4.4.1 The section modulus $W$ of transversely framed deck beams is not to be less than that obtained from the following formula:

$$W = 4.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of deck beams, in m;

$l$ — span of deck beam, in m;

$h$ — head taken in calculation, in m; $h = 0.14p + 0.3$, but not to be less than $0.02L + 0.76$ m, $L$ being length of ship, in m, $p$ being design load, in kPa;

$K$ — material factor.

12.4.4.2 The section modulus $W$ of longitudinally framed deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of deck longitudinals, in m;

$l$ — span of deck longitudinal, in m;

$h$ — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;

$K$ — material factor.

12.4.4.3 The section modulus $W$ of deck girders (including top chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: $S$ — average width of areas supported by girders, in m;

$l$ — span of girders, in m;

$h$ — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;

$K$ — material factor.

12.4.4.4 The section modulus $W$ of deck transverses (including top chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: $S$ — average width of areas supported by transverses, in m;

$l$ — span of transverses, in m;

$h$ — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;

$K$ — material factor.

12.4.4.5 Primary structural members of deck (including deck girders and transverses) are to comply with the following requirements:

(1) The web depth $h$ of primary members is not to be less than 2 times the depth of the slot for the passage

of secondary members (deck beams and longitudinals), and not to be less than that obtained from the following formula:

$$h = 58.5l \quad \text{mm}$$

where: $l$ — span of primary member, in m.

(2) The web thickness $t$ of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \quad \text{mm, not less than 7 mm}$$

where: $h$ — web depth of primary members, in mm.

12.4.4.6 Where wheeled vehicles are stowed on the deck, the deck framing is also to comply with the relevant requirements in Section 21, Chapter 2 of this PART.

12.4.4.7 Where containers are carried on the deck, stacking devices are to be fitted on supporting members, and the strength of deck framing is to be checked by direct calculation. The static load of containers is to be taken as the load in calculation, and permissible stresses are as follows:

Permissible normal stress $[\sigma] = 0.5R_{eH}$

Permissible shear stress $[\tau] = 0.292\ R_{eH}$

where: $R_{eH}$ — yield stress of material, in N/mm$^2$.

### 12.4.5 Truss structure of pontoon barges

12.4.5.1 Pontoon barges are to be fitted with trusses extending either fore and aft or athwartships for the support of hull structure.

12.4.5.2 A truss is comprised of top and bottom girders, pillars and diagonal bracings.

12.4.5.3 The top and bottom girders of longitudinal trusses are deck and bottom girders respectively.

12.4.5.4 The top and bottom girders of transverse trusses are deck transverses and bottom webs respectively.

12.4.5.5 Pillars are to comply with the relevant requirements of Section 10, Chapter 2 of this PART, and the load $P$ acting on pillars is to be taken as the greater of the values obtained from the following formulae:

$$P_1 = pa_1b_1 \quad \text{kN}$$

$$P_2 = 10D\ a_2b_2 \quad \text{kN}$$

where: $p$ — design cargo load, in kPa;

$a_1$ — average length of deck area supported by pillar, in m;

$b_1$ — average width of deck area supported by pillar, in m;

$D$ — moulded depth, in m;

$a_2$ — average length of bottom area supported by pillar, in m;

$b_2$ — average width of bottom area supported by pillar, in m.

12.4.5.6 Diagonals are generally to have an angle of inclination with the horizontal of 45º, and a cross-sectional area of generally 50% of that of the adjacent pillar.

## Section 5 STRENGTHENING AT ENDS OF SHIP

### 12.5.1 General requirements

12.5.1.1 The ends of barges with general sea-going-ship-shaped bow forms are to be strengthened in accordance with Section 15, Chapter 2 of this PART.

12.5.1.2 The ends of fore rake end pontoon barges are to be strengthened in accordance with this Section. Figure 12.5.1.2 shows the shape and structural arrangement of a typical fore rake end.

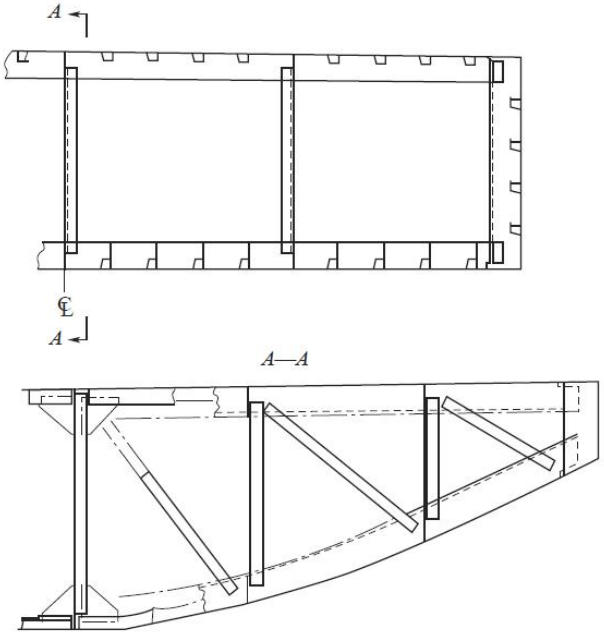



**Figure 12.5.1.2**

### 12.5.2 Structural requirements for fore rake end

12.5.2.1 The structural requirements for fore rake end apply to the bottom forward plating of the forward rake from the forward headlog to the lower turn of the rake. Where the collision bulkhead is located aft of the lower turn of the rake, these requirements apply to the bottom forward plating of the forward rake from the forward headlog to the collision bulkhead.

12.5.2.2 The span of bottom longitudinals is not to exceed 2.5 m. Bottom longitudinals may be supported by transverse bulkheads or bottom webs.

12.5.2.3 The span of bottom frames is not to exceed 2.5 m. Bottom frames may be supported by longitudinal bulkheads or bottom girders.

12.5.2.4 The scantlings of primary members are to comply with the relevant requirements for pontoons in Section 4 of this Chapter and in addition, the following requirements:

(1) In general, the web depth of primary members is not to be less than 2.5 times the depth of the slot for the passage of secondary members.

(2) The web depth $h$ of primary members is not to be less than that obtained from the following formula:

$$h = Cl \quad \text{mm}$$

where: $l$ — span of primary members, in m;

$C$ — coefficient, taken as follows:

83.5 for deck transverses;

125 for side transverses;

156 for bottom webs.

12.5.2.5 The bottom shell plating thickness is to be maintained up to the summer load waterline for the rake plating. Above this point the thickness may be tapered to that of the side shell requirements from a point not less than 1 m above the load waterline.

### 12.5.3 Strengthening of structures of bottom forward against slamming

12.5.3.1 The structures of bottom forward are to be strengthened against slamming in accordance with 2.15.3 of Section 15, Chapter 2 of this PART.

12.5.3.2 Where pontoon barges are towed or pushed at a speed of less than 10 kn and minimum fore draught equal to or greater than $0.01L$ ($L$ being length of ship, in m), with trim being kept at zero, the requirements for strengthening of bottom forward in Section 15, Chapter 2 of this PART may be dispensed with.

# Appendix METHOD OF CHECKING TRANSVERSE STRENGTH OF PONTOON BARGES

## 1. General Requirements

### 1.1 Application

1.1.1 This method is applicable only to the check of transverse strength of pontoon barges in accordance with 12.1.3.7 of this Chapter.

1.1.2 This method is not applicable to the strength assessment of local structures subjected to a concentrated load (e.g. large foundation, heavy cargo support and struts).

## 2. Loads

### 2.1 Load types

2.1.1 Only the effects of maximum permissible deck load and external water pressure are taken into account for design conditions of transverse strength. The effects of hull girder bending moments (both vertical and horizontal ones) are not taken into account.

2.1.2 The load due to external water pressure consists of hydrostatic pressure and hydrodynamic wave pressure as follows:

at baseline: $P_B = 10d \pm 1.5C$ kN/m$^2$

at waterline: $P_w = \pm 3C$ kN/m$^2$

at side top: $P_s = 3P_0$ kN/m$^2$

where: $C$ – see 2.2.3.1 of Section 2, Chapter 2;

$d$ – draught, in m;

$P_0$ – to be calculated as follows:

$P_0 = C - 0.67(D - d)$ kN/m$^2$;

$D$ – moulded depth, in m.

In order to take account of the effects of beam sea acting along the ship's length in local areas, such effects are simulated by applying asymmetric external water pressure on both sides for design conditions. A superimposition of hydrostatic pressure and wave pressure may be assumed on one side and the effects of hydrostatic pressure and reverse hydrodynamic wave pressure on the other side ($C$ being taken negative in the above formula), where any value below zero is to be taken as zero.

The distribution of load effects is shown in Figure 2.1.2.

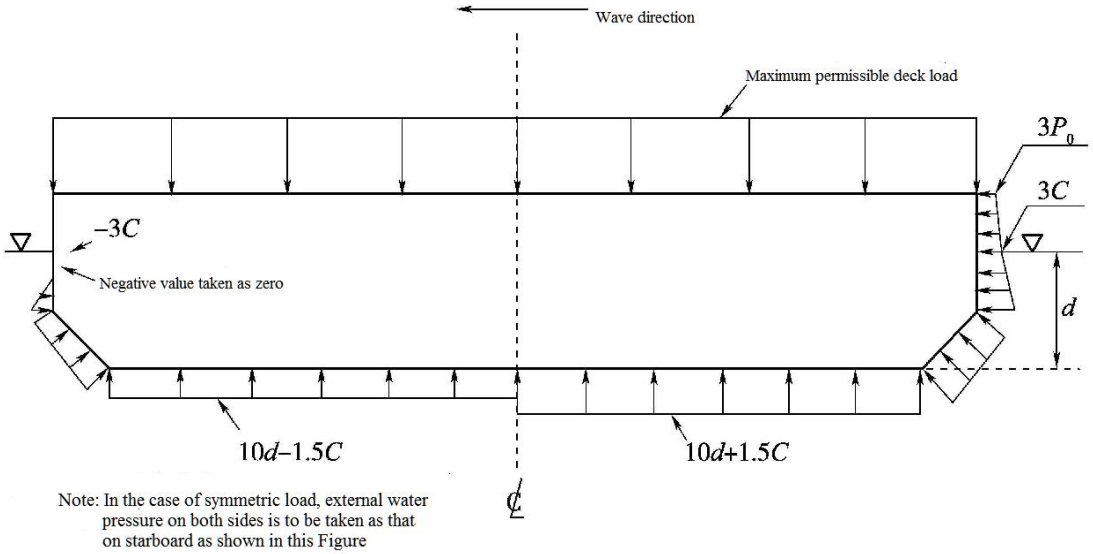



**Figure 2.1.2**

2.1.3 The following two conditions are taken into account for design conditions:

(1) **Symmetric condition**: Maximum permissible deck load+ external hydrostatic pressure + hydrodynamic wave pressure acting symmetrically inwards on both sides;

(2) **Asymmetric condition**: Maximum permissible deck load + external hydrostatic pressure + antisymmetric hydrodynamic wave pressure acting inwards on one side and outwards on the other side.

2.1.4 For pontoon barges only engaged in restricted navigation zones, the *C* value used in calculation in 2.1.2 may be reduced according to the following provisions:
(1) offshore navigation zone: 0.90;
(2) coastal navigation zone: 0.85;
(3) shield navigation zone: 0.80.

## 3. Structural Models

### 3.1 Structural modelling

#### 3.1.1 Model extent

① Longitudinal direction: In general, a typical midship hold/tank is to be taken for analysis, with fore and aft end faces (A and B) being at transverse bulkheads covered by the model;
② Transverse direction: Total breadth of the ship;
③ Vertical direction: Total moulded depth.
See Figure 3.1.1.

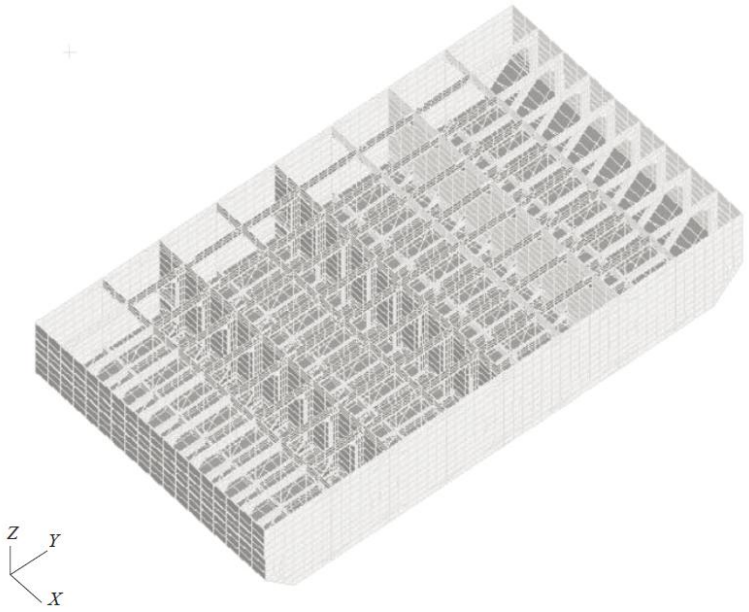



**Figure 3.1.1 Model Extent (deck not shown)**

#### 3.1.2 Elements and meshing size of models

3.1.2.1 The elements and meshing size of models are to be in accordance with those specified for general finite element hold models, refer to 1.5.6, Chapter 1 of this PART.
3.1.2.2 The diagonals of transverse trusses are generally simulated by rod elements.

#### 3.1.3 Boundary conditions

3.1.3.1 All nodes at edges of fore and aft end transverse bulkheads are to be restrained for 3 linear deflections, see Figure 3.1.3.1.

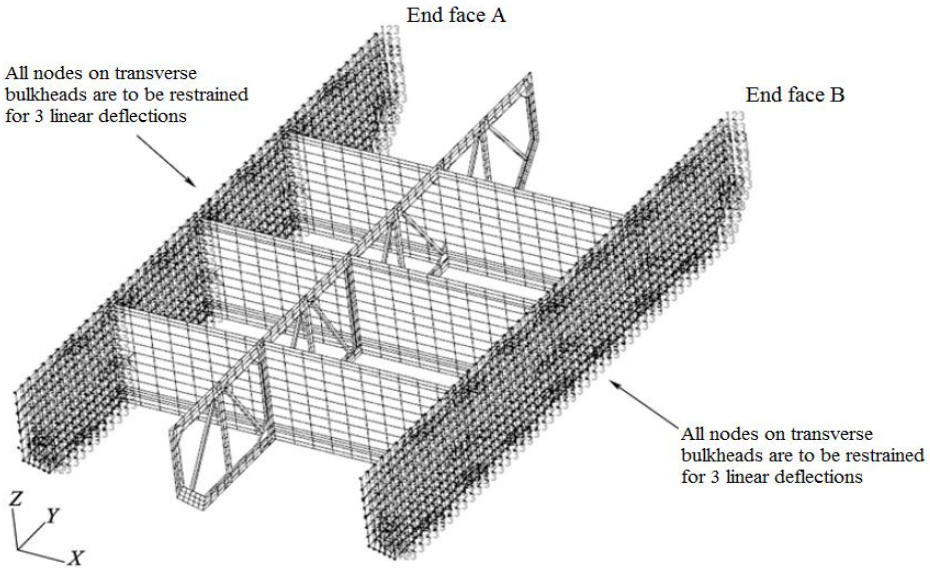


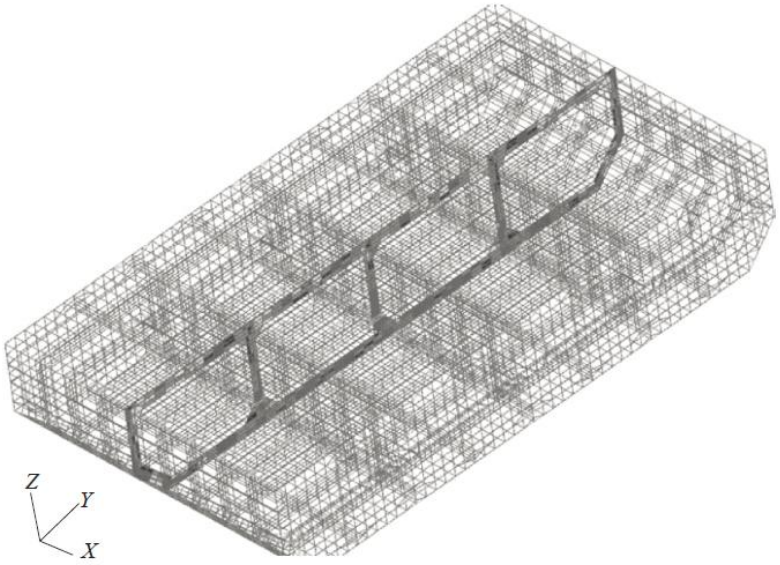

**Figure 3.1.3.1 Boundaries Conditions of Model**

## 4. Strength Assessment

### 4.1 General requirements

#### 4.1.1 Assessment of results

4.1.1.1 The range of values for assessment of the results of finite element analysis is to be based on one of the web frames of the model, see Figures 4.1.1.1.




**Figures 4.1.1.1**

4.1.1.2 For floors and beam webs, the average shear stress based on the total height of webs may be taken as the shear stress in calculation.

### 4.2 Assessment of yield strength

#### 4.2.1 Strength criteria

4.2.1.1 In all conditions, the calculated stress of individual structural members is not to be greater than the corresponding permissible values given in Tables 4.2.1.1(1) and (2).

**Plate Element** **Tables 4.2.1.1(1)**

| Structural member | $[\sigma_e]$ | $[\tau]$ |
|---|---|---|
| Side transverse web, longitudinal bulkhead vertical girder web | 170/*K* | – |
| Deck transverse web, bottom floor | 170/*K* | 90/*K* |

**Beam and Rod Elements** **Tables 4.2.1.1(2)**

| Structural member | $[\sigma_{rod}]$ |
|---|---|
| Beam element simulating web faceplate of strength member of transverse web frame or beam fitted on transverse members | 170/*K* |
| Cross tie of transverse truss | 141/*K* |

where: $\sigma_e$ – equivalent stress of plate element (i.e. Von Mises stress), in N/mm$^2$;

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$ , based on membrane stress at centroid of the element

$\sigma_x$ – stress of element in direction *X*, in N/mm$^2$;

$\sigma_y$ – stress of element in direction *Y*, in N/mm$^2$;

$\tau_{xy}$ – shear stress of element in plane *XY*, in N/mm$^2$;

$\tau$ – average shear stress based on the total height of webs, in N/mm$^2$;

$\sigma_{rod}$ – axial stress of rod element or normal stress of beam element (excluding bending stress component), in N/mm$^2$;

*K* – material factor.

# CHAPTER 13 FLOATING CRANES

## Section 1 GENERAL PROVISIONS

### 13.1.1 Application

13.1.1.1 This Chapter applies to single-deck crane barges with both deck and bottom framed longitudinally.

13.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

### 13.1.2 Definitions

13.1.2.1 Fore end and aft end: The fore end and aft end of non-self-propelled floating cranes are to be determined according to their operation conditions. During transit, the floating cranes are to be treated as ordinary ships with the fore end of the hull in forward direction called the fore end and the opposite end the after end. In conditions other than transit, the end where the crane jib is fitted is called the fore end and the opposite end the aft end.

### 13.1.3 Arrangement and structures

13.1.3.1 The primary longitudinal members are to be continuous from the fore end to the aft end as far as possible.

13.1.3.2 Two or more continuous longitudinal bulkheads (or longitudinal trusses) are to be fitted from the fore end to the aft end.

13.1.3.3 One transverse watertight bulkhead is to be fitted at a suitable position at each end of the barge. Between the end bulkheads, at least one intermediate transverse watertight bulkhead is to be fitted for barges not exceeding 50 m in length, and at least two intermediate transverse watertight bulkheads are to be fitted for barges exceeding 50 m in length. Such transverse bulkheads are to be arranged reasonably uniform.

13.1.3.4 Longitudinal or transverse supporting bulkheads or other effective structures with sufficient strength and rigidity are to be fitted underneath the cranes to provide adequate support. Such strengthened structures are to be so arranged as to effectively transmit stresses. The deck plating in way of the cranes is to be increased in thickness or fitted with doublers. The thickness of doublers is not to be less than that of the deck plating. In addition, local strengthening is to be provided to the hull structure in way of other deck machinery or where heavy loads impose on.

## Section 2 LONGITUDINAL STRENGTH

### 13.2.1 General requirements

13.2.1.1 The longitudinal strength is to comply with the relevant requirements in Section 2, Chapter 2 of this PART. Transit and lifting conditions are to be taken into account.

13.2.1.2 For fixed type floating crane, where the still water bending moment obtained from calculation is a sagging moment in lifting conditions, an additional bending moment (sagging moment) induced by the maximum horizontal component force which is imposed on the hull structure by the maximum load lifted is to be added.

13.2.1.3 For lifting conditions, the wave bending moment and wave shear force regarding the intended area of operation may be determined according to Section 7, Chapter 1 of this PART.

## Section 3 SHELL PLATING

### 13.3.1 Minimum thickness

13.3.1.1 The minimum thickness $t$ of shell plating is not to be less than that obtained from the following formula:

$$t = 0.044L + 5.6 \quad \text{mm}$$

where: $L$ — length of ship, in m.

### 13.3.2 Bottom shell

13.3.2.1 The thickness $t$ of bottom shell plating within 0.5$L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.32s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m;
$L$ — length of ship, in m;
$K$ — material factor.

**13.3.3 Side shell plating**

13.3.3.1 The thickness $t$ of side shell plating within 0.5$L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.27s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of frames, in m;
$L$ — length of ship, in m;
$K$ — material factor.

# Section 4 DECKS

**13.4.1 Thickness of deck plating**

13.4.1.1 The thickness $t$ of strength deck plating within 0.5$L$ amidships is not to be less than that obtained from the following formula:

$$t = 8.75s\sqrt{K} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of longitudinals, in m;
$K$— material factor.

13.4.1.2 The thickness $t$ of strength deck plating outside 0.5$L$ amidships is not to be less than that obtained from the following formula:

$$t = 7.13s\sqrt{K} + 2.5 \quad \text{mm}$$

where: s – spacing of longitudinals, in m.
$K$— material factor.

13.4.1.3 The thickness of deck plating in the cargo area is, in addition, not to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \quad \text{mm, but not less than 6 mm}$$

where: $s$ — spacing of beams or longitudinals, in m;
$h$ — design head, in m, to be taken as 0.14$p$ + 0.3, $p$ being the design load, in kPa;
$K$ — material factor.

# Section 5 SINGLE BOTTOMS

**13.5.1 Centre keelson**

13.5.1.1 Floating cranes are to be provided with a centre keelson and with side keelsons fitted on each side of the centre keelson, spaced not more than 2.5 m apart.

13.5.1.2 The web thickness $t$ and the sectional area $A$ of the face plate of the centre keelson are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$
$$A = 0.60L + 9 \quad \text{cm}^2$$

where: $L$ — length of ship, in m.

**13.5.2 Side keelsons**

13.5.2.1 The web thickness $t$ and the sectional area $A$ of the face plate of side keelsons are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$
$$A = 0.24L + 10 \quad \text{cm}^2$$

where :$L$ — length of ship, in m.

**13.5.3 Plate floors**

13.5.3.1 The spacing of plate floors is not to exceed 2.5 m.

13.5.3.2 The section modulus $W$ of plate floors is not to be less than that obtained from the following formula:

$$W = 4Shl^2K \quad \text{cm}^3$$

where: $S$ — spacing of floors, in m;

$K$ — material factor;

$h$ — design head, in m, to be taken as $d$ or $0.66D$, whichever is the greater ($d$ and $D$ being draught and moulded depth respectively, in m);

$l$ — span of floor, in m.

13.5.3.3 The web depth $h$ of floors is not to be less than that obtained from the following formula and in addition, this depth should be greater than 2.5 times the depth of the slot for the longitudinals:

$$h = 60l_1 \quad \text{mm}$$

where: $l_1$ — horizontal distance between longitudinal bulkheads or between the longitudinal bulkhead and side shell, in m.

### 13.5.4 Bottom longitudinals

13.5.4.1 The section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.90shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$K$ — material factor;

$h$ — design pressure head, in m, to be taken as $d$ or $0.66D$, whichever is the greater ($d$ and $D$ being draught and moulded depth respectively, in m);

$l$ — span of longitudinal, in m.

## Section 6 DOUBLE BOTTOMS

### 13.6.1 General requirements

13.6.1.1 Where double bottoms are provided, the height $h$ of the double bottom is to be determined by the following formula, but not to be less than 700 mm:

$$h = b/18 \quad \text{mm}$$

where: $h$ – horizontal distance between longitudinal bulkheads (or longitudinal trusses), in mm.

13.6.1.2 The thickness of the centre girders, side girders, plate floors and inner bottom plating within the machinery space is to be increased by 2 mm above that obtained from the respective formulae set forth in this Section.

### 13.6.2 Centre girders

13.6.2.1 The thickness $t$ of centre girders is not to be less than that obtained from the following formula:

$$t = 0.05L + 4 \quad \text{mm}$$

where: $L$ — length of ship, in m.

### 13.6.3 Side girders

13.6.3.1 The thickness $t$ of side girders is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \quad \text{mm}$$

where: $L$ — length of ship, in m.

### 13.6.4 Plate floors

13.6.4.1 The thickness $t$ of plate is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \quad \text{mm}$$

where: $L$— length of ship, in m.

### 13.6.5 Inner bottom plating

13.6.5.1 The thickness $t$ of inner bottom plating is not to be less than that obtained from the following formula:

$$t = 0.67s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of the inner bottom longitudinals, in m;

$K$ — material factor;
$L$ — length of ship, in m.

**13.6.6 Longitudinals**

13.6.6.1 The section modulus of bottom longitudinals is to be determined in accordance with 13.5.4.1 of this Chapter.

13.6.6.2 The section modulus of inner bottom longitudinals is to be 85 % of that of the bottom longitudinals.

# Section 7 SIDE FRAMING

**13.7.1 Side transverses**

13.7.1.1 Side transverses are to be fitted in line with the plate floors and their section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 9.5Shl^2K \quad \text{cm}^3$$

where: $S$ — spacing of side transverses, in m;
$K$ — material factor;
$h$ — vertical distance, in m, measured from the mid-point of span of the side transverse to upper deck at side;
$l$ — span of side transverse, in m.

13.7.1.2 The web depth $h$ of side transverses is not to be less than that obtained from the following formula and in addition, this depth is to be greater than twice the depth of the slot for the longitudinals:

$$h = 100l \text{ mm}$$

where: $l$ — span of side transverse, in m.

# Section 8 STRENGTH DECK FRAMING

**13.8.1 Strength deck loading**

13.8.1.1 The design head $h$ of the strength deck is to be selected from Table 13.8.1.1.

**Design head $h$** **Table 13.8.1.1**

| Item | Deck longitudinals | Deck girders and deck transverses | Pillars |
|---|---|---|---|
| Design head $h$, in m | $0.02L + 0.76$ | $0.085L - 1.04(D - d)$ | $0.098L - 1.1(D - d)$ |

Note: $L$ is length of ship, $D$ moulded depth and $d$ draught, in m.

13.8.1.2 Where the deck is subject to load, the design head is to be taken as $0.14p$ ($p$ being the design load, in kPa), in m, but not to be less than the corresponding design head $h$ given in Table 13.8.1.1.

**13.8.2 Deck girders**

13.8.2.1 The section modulus $W$ of deck girders is not to be less than that obtained from the following formula:

$$W = 3.5bhl^2K \quad \text{cm}^3$$

where: $b$ — mean width, in m, of deck area supported by the girder;
$K$ — material factor;
$l$ — span of deck girder, in m;
$h$ — design head of deck, in m, see 13.8.1 of this Section.

**13.8.3 Deck transverses**

13.8.3.1 Deck transverses are to be fitted in line with the side transverses and their section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 3.9Shl^2K \quad \text{cm}^3$$

where: $S$ — spacing of deck transverses, in m;
$K$ — material factor;
$l$ — span of deck transverse, in m;
$h$ — design head of deck, in m, see 13.8.1 of this Section.

13.8.3.2 The web depth of deck transverses is not to be less than twice the depth of the slot for the longitudinals.

### 13.8.4 Deck longitudinals

13.8.4.1 The section modulus $W$ of deck longitudinals is not to be less than that obtained from the following formula:

$$W = 8.5shl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$K$ — material factor;
$h$ — design head of deck, in m, see 13.8.1 of this Section;
$l$ — span of longitudinal, in m.

## Section 9 PILLARS AND TRUSSES

### 13.9.1 Pillars

13.9.1.1 Pillars are to comply with the relevant requirements of Section 10 of Chapter 2 of this PART, but the design head $h$ of pillars underneath the strength deck is to be determined by 13.8.1 of this Chapter.

### 13.9.2 Longitudinal trusses

13.9.2.1 Longitudinal trusses are to be composed of deck girders, keelsons, pillars and diagonals.

13.9.2.2 The sectional area of pillars of the longitudinal trusses is to comply with the requirements of Section 10 of Chapter 2 of this PART.

13.9.2.3 Diagonals of trusses

(1) The angle of inclination of diagonals of trusses is to be about 45°

(2) The sectional area of diagonals of trusses is not to be less than 0.5 times that of the pillars calculated according to Section 10 of Chapter 2 of this PART and the ratio of the length of the diagonal to its minimum sectional radius of inertia is not to exceed 120.

# CHAPTER 14 DREDGERS

## Section 1 GENERAL PROVISIONS

### 14.1.1 Application

14.1.1.1 This Chapter applies to self-propelled or non-self-propelled steel dredgers with a single deck, including:

(1) trailing suction dredger;
(2) cutter suction/cutter wheel dredger;
(3) bucket dredger;
(4) grab dredger;
(5) hopper barge;
(6) reclamation craft;
(7) split hopper dredger;
(8) split hopper barge.

Dipper dredgers may be referred to the requirements given in this Chapter and are to be adequately strengthened.

14.1.1.2 If not covered in this Chapter, the requirements of Chapter 2 of this PART are to be compiled with.

14.1.1.3 The provisions of this Chapter are applicable to the following proportions of principal dimensions of dredgers or barges:

For hopper dredgers: $B/D \leq 3$

For other types of dredgers: $B/D \leq 5$

Where any of the above values is exceeded, the transverse strength is to be checked by direct calculation.

### 14.1.2 Plans and documents

14.1.2.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans covering the following items are to be submitted for approval:

(1) Sections through hoppers, pump rooms, dredging machinery spaces and wells;
(2) Hopper and well bulkheads (including sloping bottom structure) and associated regions;
(3) Scarfing arrangements at hopper and well bulkheads (including sloping bottom structure);
(4) If dredging equipment is stored during voyages, plans of any special arrangements for dismantling, storage and re-assembly;
(5) Seats of dredging equipment (directly affecting the primary hull structure) together with their supporting structures;
(6) For split hopper barges and split hopper dredgers:
① Structure of junction piece of hydraulic installation;
②Deck hinges, deckhouse hinges (appropriate strength calculations are submitted for information);
③ Connection of hinges to hull structure;
④ Connection of junction piece of hydraulic installation to hull structure;
⑤ Longitudinal bearing plate of bottom plane and deck plane;
⑥ Longitudinal bearing plate of deckhouse and its connection to hull structure;
⑦ Transverse bearing plate.

14.1.2.2 The following plans and documents are to be submitted for information (where applicable):

(1) Arrangement of dredging equipment (including the design load of dredging equipment).

### 14.1.3 Definitions

14.1.3.1 **Hopper**: A hopper is a hold designed to carry dredged spoil and arranged to be opened from the dredger or hopper barge to enable the spoil to be automatically discharged through the doors in the bottom of the ship.

14.1.3.2 **Box keel**: The box keel is a built-up box-shaped structure on the centreline, consisting of bottom plating, side plating in the hopper and internal framing, arranged longitudinally at the lower portion, and between the fore and aft end bulkheads, of the hopper or hoppers.

14.1.3.3 **Cross beam**: Cross beam is a built-up beam spanning transversely the longitudinal bulkheads or hatch coaming of the hopper within the lines of deck openings.

14.1.3.4 **Longitudinal cross beam**: Longitudinal cross beam is a longitudinal built beam spanning longitudinally the fore and aft transverse bulkheads of the hopper within the lines of deck openings.

14.1.3.5 **Well**: The recess or well in the hull of dredgers for arranging the dredging gear.
14.1.3.6 **Split hopper barge or split hopper dredger**: Hopper barge or hopper dredger composed of two independent half hulls separating longitudinally along the hull, with the half hulls being connected by deck hinges and hydraulic installation at the fore and aft transverse bulkheads of the hopper.

# Section 2 LONGITUDINAL STRENGTH

### 14.2.1 General requirements

14.2.1.1 The provisions of this Section are applicable to dredgers and barges 65 m or over in length. The requirements for longitudinal strength of split hopper dredgers and barges are given in Section 9 of this Chapter.
14.2.1.2 The continuous longitudinal members such as longitudinal bulkheads of hoppers and wells and box keels are to be so arranged as to ensure smooth transition at the break, and abrupt changes at the breaks are to be avoided.
14.2.1.3 For dredgers and barges complying with the requirements of 14.1.1.1, the strength of large openings at hoppers need not be checked.

### 14.2.2 Bending strength of hull girders

14.2.2.1 Midship section modulus is to comply with the following requirements:
(1) The minimum midship section modulus $W_0$ is not to be less than that obtained from the following formula:

$$W_0 = CL^2B(C_b + 0.7)K \quad \text{cm}^3$$

where: $C$ — coefficient, to be determined by 2.2.3.1 of Section 2, Chapter 2 of this PART;
$L$ — length of ship, in m;
$B$ — breadth of ship, in m;
$C_b$ — block coefficient at design summer load waterline, but to be taken as not less than 0.6 in calculation;
$K$ — material factor.

The value of $W_0$ is to be generally maintained throughout 0.4$L$ amidships. However, it may be reduced away from the midship point provided that it complies with the requirements in (2) below.
(2) In 0.4$L$ amidships, section modulus $W$ at deck, keel and top of hopper hatch coaming (where applicable) in way of each transverse section is not to be less than that obtained from the following formulae:

For dredging condition: $W = \dfrac{M_{sd} + M_w}{[\sigma]} \times 10^3 \quad \text{cm}^3$

For transit condition: $W = \dfrac{M_s + M_w}{[\sigma]} \times 10^3 \quad \text{cm}^3$

where: $M_{sd}$ — still water bending moment when dredging, in kN • m, to be determined by 14.2.5.1 of this Section;
$M_s$ — still water bending moment in transit, in kN • m, to be determined by 14.2.5.1 of this Section;
$M_w$ — wave bending moment, in kN • m, to be determined by 2.2.3.1 of Section2, Chapter 2 of this PART;
[σ]— permissible bending stress, in N/mm², to be in compliance with 2.2.5.4(2) of Section 2, Chapter 2 of this PART.

### 14.2.3 Midship section moment of inertia

14.2.3.1 For hopper dredgers or hopper barges, the midship section moment of inertia $I$ to horizontal neutral axis is not to be less than that obtained from the following formula:

$$I = 3.5W_0L/K \quad \text{cm}^4$$

where: $W_0$ — midship section modulus, in cm3, as required in 14.2.2.1(1) of this Section;
$L$ — length of ship, in m;
$K$ — material factor.

### 14.2.4 Shear strength of hull girders

14.2.4.1 Hopper dredgers or hopper barges are to be checked for their shear stress.
14.2.4.2 The shear stress τ at hull section near fore and aft hopper end bulkheads is to comply with the

following requirements:

For dredging condition: $\tau = \dfrac{|F_{sd} + F_w|}{2Dt} \le [\tau]$ N/mm$^2$

For transit condition: $\tau = \dfrac{|F_s + F_w|}{2Dt} \le [\tau]$ N/mm$^2$

where: $F_{sd}$ — still water shear force when dredging, in kN, to be calculated in accordance with 14.2.5.1 of this Section;

$F_s$ — still water shear force in transit, in kN, to be calculated in accordance with 14.2.5.1 of this Section;

$F_w$ — wave shear force, to be calculated in accordance with 2.2.3.2 of Section 2, Chapter 2 of this PART;

$D$ — moulded depth, in m;

$t$ — sum of mean thicknesses of side plating and longitudinal bulkhead plating respectively, or mean thickness of side plating, in mm;

$[\tau]$ — the same as that in 2.2.6.2 of Section 2, Chapter 2 of this PART, but $[\tau]$ = 110 N/mm² where higher tensile steel is adopted partially for the hull.

Where the shear stress obtained from calculation is greater than [τ], the thickness of shell plating is to be increased. The strengthened scope along the length of ship is to be extended to the outside of the hopper end bulkhead0.04$L$ ($L$ being the length of ship, in m).

### 14.2.5 Design still water bending moment and design still water shear force

14.2.5.1 Still water bending moment and still water shear force of each transverse section of hull girder are to be calculated in accordance with the following dredging condition and transit condition, considering the influence of departure and arrival:

(1) maximum loaded condition corresponding to maximum dredging draft;

(2) where more than one hopper are fitted, the partially loaded conditions when the hoppers are not emptied simultaneously;

(3) transit condition at summer load line draft;

(4) ballast transit condition with hopper spaces empty, if this case is technically possible;

(5) the loading condition which is more severe than above.

### 14.2.6 Calculation of midship section modulus and moment of inertia

14.2.6.1 When calculating the midship section modulus and moment of inertia, the following requirements are to be complied with:

(1) Strength deck and all continuous longitudinal members below the strength deck may be included in the calculation of midship section modulus and moment of inertia.

(2) For continuous hatch coamings, where efficiently supported by longitudinal bulkheads or higher web, 100% of their sectional areas may be included in the calculation, otherwise only 80% of their sectional areas may be included.

(3) For longitudinal cross beams with smooth transition at their ends, 60% of their sectional areas may be included.

(4) For box keels with smooth transition at their ends, 85% of their sectional areas may be included.

(5) Where the openings cut in the wed of longitudinal girders exceed 20% of the height of the web, the sectional areas of the openings are to be deducted.

In general, the sectional areas of the overflows at side need not be deducted, provided the overflows comply with the requirements of 14.10.3.1, Section 10 of this Chapter.

## Section 3 SHELL ENVELOPE PLATING

### 14.3.1 Bottom shell

14.3.1.1 The thickness of bottom shell plating of hopper dredgers and barges is to be 15% greater than that required in 2.3.1.2 and 2.3.1.3 of Section 3, Chapter 2 of this PART.

### 14.3.2 Plate keel

14.3.2.1 Where a well or a hopper door is provided on the longitudinal centerline, plate keel is to be laid on both sides of the well or the hopper door. The width of plate keel on each side is not to be less than half that required in 2.3.2.1 of Section 3, Chapter 2 of this PART. The position of plate keel is to be indicated

on the docking plan.
14.3.2.2 The thickness of plate keel is to be 2 mm greater than that required for the bottom shell.

### 14.3.3 Openings in shell plating

14.3.3.1 The corners of hopper door openings and of wells are to be rounded, and the ratio of radius of corners to width of openings is not to be less than 1/10.
14.3.3.2 Openings are generally not to be cut in sheer strakes, otherwise the requirements of 14.10.3.1, Section 10 of this Chapter are to be complied with.

### 14.3.4 Local strengthening and special requirements

14.3.4.1 The thickness of the bottom shell adjacent to the hopper longitudinal bulkheads or to the well bulkheads is to be 1 mm greater than that required in this Section, and the width of which is not to be less than that of the plate keel.
14.3.4.2 Where hoppers extend outside 0.4$L$ amidships, the thickness of side shell amidships is to be maintained for at least two frame spaces beyond the ends of the hoppers and then gradually tapered to the end thickness.
14.3.4.3 The thickness of the structure in way of the suction pipe connections of the trailing suction dredgers and in way of the positioning spuds of cutter suction dredgers or bucket dredgers, as well as the thickness of the well bulkheads are to be 2 mm above that required for side shell.
14.3.4.4 In areas where the drag head may run against bilge and side shell, strengthening is to be provided, e.g. plating of increased thickness, additional framing or fitting of fenders.
14.3.4.5 Where a suction pipe well cut into shell plating is provided at the side of the trailing suction dredgers, a stinger sheathing is to be provided in a scope enough long along the length of ship. The thickness of sheathing is not to be less than that of shell plating, and the breadth is to cover the stinger. The stinger sheathing is to be strengthened by side transverses and stringers at its inner side. The stringers are to have scantlings large enough to bear the load transferred from side longitudinals so as to keep the continuity of longitudinal structures.
14.3.4.6 The well width of bucket dredgers is to be such that the overhang part of the bucket chain will not collide the lower well wall under maximum allowable working inclination.
14.3.4.7 The thickness of the bottom plate of bucket dredgers that is connected to end well bulkheads is to be increased by 50%. The thickness-increased part is not to be less than twice the well width along the breadth of the ship, and is to be extended fore and aft for at least two frame spaces from end bulkhead plating along the length of the ship.
14.3.4.8 Fenders are to be fitted to the longitudinal bulkheads of wells in bucket dredgers to guard against damages due to the movement of bucket ladder.

## Section 4 DECKS AND DECK FRAMING

### 14.4.1 Strength deck

14.4.1.1 The thickness of midship strength deck plating is, in addition to complying with the requirements of Section 2 of this Chapter, is to be increased by 1 mm above that required in Section 4, Chapter 2 of this PART.
14.4.1.2 In the case of dredgers having closed hopper spaces, the thickness of deck plating in way of the hopper spaces is to be adequately increased.

### 14.4.2 Half sectional area of deck

14.4.2.1 For dredgers and hopper barges less than 65 m in length, the half sectional area $a$ of midship strength deck plating is not to be less than that obtained from the following formula:
For box-shaped ship:

$$a = C_1 \frac{B}{D} - C_2 D t_1 + C_3 (B - b)\, t_2 \quad \text{cm}^2$$

For hopper barge:

$$a = C_1 \frac{B}{D} - 1.6 D t_1 - 3.05 D t_3 \quad \text{cm}^2$$

where: $B$ — breadth of ship, in m;
$D$ — moulded depth, in m;
$b$ — the width of well or opening at the midship bottom, in m;
$t_1$ — the thickness of side shell required in 2.3.4 of Section 3, Chapter 2 of this PART, in mm, $t_1$ is

to be included in the thickness of longitudinal bulkheads for ships having continuous longitudinal bulkheads within 0.4$L$ amidships;

$t_2$ — the thickness of continuous inner bottom plating within 0.4$L$ amidships, in mm;

$t_3$ — the thickness of web of continuous longitudinal hatch coamings, in mm;

$C_1 = 0.065L^2 - L + 9$ ($L$ being length of ship, in m);

$C_2$, $C_3$ — coefficient, to be taken from Table 14.4.2.1.

**Values of $C_2$ and $C_3$** **Table 14.4.2.1**

| Type of ship structure | $C_2$ | $C_3$ |
|---|---|---|
| Box-shaped ship without continuous longitudinal bulkhead within 0.4$L$ amidships | 2. 15 | 0. 32 |
| Box-shaped ship with continuous longitudinal bulkhead within 0.4$L$ amidships | 3. 07 | 0. 205 |

The above-mentioned half sectional area of deck plating is the sum of sectional areas of continuous longitudinal members, such as deck plating, stringer strakes, deck longitudinals and deck girders outside the lines of large openings and at one side of the longitudinal midship line of the deck. For longitudinal cross beams having smooth transition at both ends, 60 % of their sectional areas may be included.

The thickness of deck plating derived from the half sectional area of decks is not subject to reduction for service conditions.

### 14.4.3 Deck framing

14.4.3.1 Where the deck of side tanks is framed transversely, deck transverses are to be fitted in the plane of web frames in the side tanks, the web height of which is to be 2/3 of that of the web frame, and the web thickness and the face plate area of which are to be the same as those of the web frame.

14.4.3.2 For dredgers having a closed hopper space, the section modulus of deck framing within the hopper region is to be increased by 10 % as required in Section 8, Chapter 2 of this PART.

14.4.3.3 For trailing suction dredgers, the section modulus of deck longitudinals within the hopper and side tank region is to be increased by 20% of that required in Section 8, Chapter 2 of this PART.

### 14.4.4 Local strengthening

14.4.4.1 For bucket and cutter suction dredgers, the thickness of deck plating connected with the well bulkheads is to be increased by 1 mm, and the width of which is not to be less than that of the plate keel.

14.4.4.2 The thickness of the deck plating and scantlings of deck framing which are connected with the heavy dredging machinery seatings are to be designed to provide sufficient strength and rigidity and where necessary, local strength is to be checked, see the requirements of 14.10.6 of Section 10.

14.4.4.3 The deck plating and deck framings in the following regions are to be adequately strengthened:

(1) in way of the main gantry and the bucket ladder gantry;

(2) in way of the cutter gallows and the supporter of gantry (the region in way of the supporter of the hydraulically lifted cutter gallows is to have sufficient strength and rigidity and where necessary, local strength is to be checked);

(3) in way of the gantry supporting the suction pipe;

(4) in way of the spud supporter;

(5) in way of the towing bollards;

(6) in way of the winch seating;

(7) in way of the grab machinery;

(8) in way of suction pipe stinger of trailing suction hopper dredgers, the thickness of stringer strakes is to be increased by 60%, doubling is to be extended at least one frame space from side transverse at both ends of stinger;

(9) in way of other regions of working machinery.

## Section 5 BOTTOM FRAMING

### 14.5.1 General requirements

14.5.1.1 The bottom framing in pump rooms is to be strengthened in accordance with the requirements for machinery spaces.

Where the double bottom is interrupted in the pump room due to the arrangement of dredging pumps, the bottom framing in way is to be specially strengthened.

The requirements for dredging pump seatings are not to be lower than those for main engine seatings

specified in Section 16, Chapter 2 of this PART.
Where the bottom structure is connected with the seatings of other dredging equipment or special machinery, and with the bottom table of grabs or dipper machines as well as the main gantry of bucket dredgers, such bottom structure is to be adequately strengthened.
14.5.1.2 For trailing suction dredgers of 65 m or over in length, a double bottom is as far as possible to be arranged from the fore peak bulkhead to the after peak bulkhead except in the region of hopper spaces.
14.5.1.3 The double bottom structure is to comply with the requirements of Section 6, Chapter 2 of this PART.
For double bottoms framed longitudinally, the spacing of plate floors is, furthermore, to comply with the requirements for the spacing of web frames as required in 14.6.2.1, Section 6 of this Chapter.
14.5.1.4 The bottom longitudinal members in hoppers that are tapered to both ends are to be continuous. Additional side girders are to be fitted in the double bottom below the bracket of the longitudinal bulkheads of hoppers or wells. The additional side girders are to be extended at least 3 frame spaces from the end of brackets.

### 14.5.2 Single bottom with transverse framing

14.5.2.1 Abreast of dredging wells and hoppers, plate floor is to be fitted to each frame.
The section modulus $W$ and height $h$ and thickness $t$ of the web of plate floors are not to be less than those obtained from the following formulae:

$$W=(16.4sdl^2+150)K \quad \text{cm}^3$$
$$h = 110l \quad \text{mm}$$
$$t = (0.01h + 3.5)\sqrt{K} \quad \text{mm}$$

where: $s$ — spacing of floors, in m;
$K$ — material factor;
$d$ — draught, in m;
$l$ — span of floor, in m, the distance measured from the inner surface of shell plating along the face plate of floors to the inner surface of the longitudinal bulkhead or side well bulkhead of the hopper, taken as $0.3B$ for $l < 0.3B$, ($B$ being the breadth of ship, in m).
14.5.2.2 Where the distance between the ship's side and the side bulkhead of hoppers at the bottom excee.3.5 m, side keelson is to be fitted in the side tanks. The thickness of the side keelson is to be equal to that of the floor in way.

### 14.5.3 Single bottom with longitudinal framing

14.5.3.1 The section modulus $W$ of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.5sdl^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$K$ — material factor;
$d$ — draught, in m;
$l$ — span of longitudinal, in m.
The connection of bottom longitudinals to transverse bulkheads or floors is to comply with the requirements of 1.2.6 of Section 2, Chapter 1 of this PART.
14.5.3.2 The section modulus $W$ of floors in side tanks is not to be less than that obtained from the following formula:

$$W = 16.4Sdl^2K \quad \text{cm}^3$$

where: $S$ — spacing of floors, in m;
$K$ — material factor;
$d$ — draught, in m;
$l$ — span of floor, in m, the distance measured from the inner surface of shell plating along the face plate of floors to the inner surface of the hopper longitudinal bulkhead.
The depth of the web of floors in side tanks is not to be less than 1/9 of the span of the floor, and is not to be less than 2.5 times the depth of the slot for the passage of bottom longitudinals. The thickness of the web of floors is not to be less than 0.01 times the depth of the floor plus 4.5 mm.
Where one side keelson is fitted in the side tank, the section modulus of the floors may be reduced by 5%.
14.5.3.3 For box-shaped ships fitted with two longitudinal bulkheads, the floors in side tanks are to comply with the requirements of 14.5.3.2 of this Section.
The section modulus $W$ of floors in the center tank is not to be less than that obtained from the following formula:

$$W = 9Sdl^2K \quad cm^3$$

where: $S$ — spacing of floors, in m;
$K$ — material factor;
$d$ — draught, in m;
$l$ — span of floor in the center tank, in m, the distance between the longitudinal bulkheads.

The section modulus of floors in the center tank is also not to be less than that of floors in the side tanks. The depth of the web of floors in the center tank is not to be less than 1/12 of the span of the floor, and is not to be less than 2.5 times the depth of the slot for the passage of bottom longitudinals. The thickness of the web of floors is not to be less than 0.01 times the depth of the floor plus 4.5 mm.

14.5.3.4 Vertical stiffeners are to be fitted to the web of floors in way of every bottom longitudinal. The thickness of stiffeners is to be equal to that of the web of floors, and the width is to be 8 times its thickness.

### 14.5.4 Double bottom with transverse framing

14.5.4.1 Where the distance between the side shell and the hopper longitudinal bulkhead at the bottom is more than 3.5 m, side girders are to be fitted in the side tanks, and the thickness of side girders is to be equal to that of the floor in way.

### 14.5.5 Double bottom with longitudinal framing

14.5.5.1 The section modulus $W$ of bottom longitudinals is not to be less than that required in 14.5.3.1 of this Section.

The section modulus of inner bottom longitudinals is not to be less than 85% of that of bottom longitudinals.

## Section 6 SIDE FRAMING

### 14.6.1 Transverse side framing

14.6.1.1 Side stringers are , as far as practicable, to be fitted in side tanks of hopper dredgers.

### 14.6.2 Longitudinal side framing

14.6.2.1 The spacing of web frames is not to be more than $0.01L + 2.5$ m ($L$ being the length of ship, in m). For trailing suction dredgers, the spacing of web frames is also to comply with the requirements for the spacing of hopper strength frame rings.

The section modulus of web frames is to be determined in accordance with the requirements of 2.7.6.2 of Section 7, Chapter 2 of this PART.

Where horizontal cross ties and diagonal braces complying with the requirements of 14.6.3 of this Section are fitted, the section modulus of web frames may be reduced by 50%.

14.6.2.2 Tripping brackets are to be fitted to web frames in way of the cross ties and other positions in accordance with the requirements of 1.2.5.4 of Section 2, Chapter 1 of this PART.

### 14.6.3 Horizontal cross ties and diagonal braces

14.6.3.1 Where horizontal cross ties or diagonal braces are fitted in the side tanks, the sectional area $A$ and moment of inertia $I$ of which are not to be less than those obtained from the following formulae:

$$A=(1.5abh+10)K \quad cm^2$$

$$I = 3Al^2/K \quad cm^4$$

where: $a$ — spacing of cross ties or braces, in m;
$b$ — width supported by the cross tie or brace, in m, i.e. half the sum of lengths of the frame above and below the intersected cross tie or brace;
$K$ — material factor;
$h$ — pressure head under consideration, in m, the distance measured from the supporting point to the top of air pipe;
$l$ — length of the cross tie or brace including the bracket, in m.

## Section 7 BOTTOM STRENGTHENING FOR OPERATING AGROUND

### 14.7.1 Application

14.7.1.1 Where the dredgers are to operate aground or are allowed to be run aground in operation, the bottom structure is to comply with the requirements of this Section.

**14.7.2 Bottom structure strengthening**

14.7.2.1 The thickness of bottom plating is to be 20% more than that required in 2.3.1.2 and 2.3.1.3 of Section 3, Chapter 2 of this PART.

14.7.2.2 Transversely framed single bottom structures are to be strengthened as follows:

(1) Vertical stiffeners are to be fitted at bottom floor webs, spaced not greater than 1.25 m;

(2) The spacing of side keelsons is not to be greater than 2.2 m, and intermediate bulb plate longitudinals with webs of 100 mm × 10 mm or equivalent members are to be fitted.

14.7.2.3 Longitudinally framed single bottom structures are to be strengthened as follows:

(1) Bottom floors are to be spaced generally not greater than 3 frame spacings, and vertical stiffeners having the same thickness as that of bottom floors are to be fitted at bottom longitudinals;

(2) The spacing of side keelsons is not to be greater than 3 bottom longitudinal spacings;

(3) Intercostal frames are to be fitted at the midspan of bottom longitudinals.

14.7.2.4 Transversely framed double bottom structures are to be strengthened as follows:

(1) Solid bottom floors are to be fitted at each frame, with vertical stiffeners spaced generally not greater than 1.25 m;

(2) The spacing of side girders is not to be greater than 2.2 m, and bottom longitudinals are to be fitted at the mid-spacing of bottom girders. The section modulus of bottom longitudinals is to be referred to 2.6.12.2 of Section 6, Chapter 2 of this PART.

14.7.2.5 Longitudinally framed double bottom structures are to be strengthened as follows:

(1) Solid floors are to be spaced generally not greater than 3 frame spacings, and vertical stiffeners having the same thickness as that of solid floors are to be fitted at bottom longitudinals;

(2) The spacing of side girders is generally not to be greater than 4 bottom longitudinal spacings;

(3) Intercostal frames are to be fitted at the midspan of bottom longitudinals.

# Section 8 HOPPERS

**14.8.1 Application**

14.8.1.1 The requirements of this Section for bottom framing are applicable to box-shaped single-bottom hoppers.

**14.8.2 Box keels**

14.8.2.1 Thus of stiffeners of box keels are to comply with the relevant requirements of this Section for hopper bulkheads. Box keels are to be adequately strengthened in way of the hopper plate floors and the bottom end of pillars.

14.8.2.2 Where the box keep is interrupted at the hopper end bulkhead, transitional brackets of a length not less than two frame spaces are to be fitted or other effective means are to be provided to ensure a smooth transition of the box keel.

14.8.2.3 Strength frame ring is to be provided to the box keel in plane of hopper floors so as to ensure the continuity of transverse strength within the breadth of the ship.

**14.8.3 Floors in hoppers (spoil spaces)**

14.8.3.1 The depth of hopper floors is not to be less than $0.13B$ ($B$ being the breadth of ship, in m). The spacing of the plate floors is not to be more than 4.5 m, and the spacing of box floors is generally not to be more than 6 m from centre to centre. Where the spacing of box floors is more than 6 m from centre to centre, the depth of the box floors is to be increased appropriately.

14.8.3.2 The web thickness of the plate floors is not to be less than that required in 14.3.1.1, Section 3 of this Chapter. The net cross-sectional area $A$ of the web of plate floors after deducting openings, in the region for a distance equal to half depth of the floor from the ends of the calculated span, is not to be less than that obtained from the following formula:

$$A = 0.93(h_1 Sl - \alpha s_0 h_1 - \rho f S + 0.102p')K \quad \text{cm}^2$$

where: $S$ — spacing of floors, in m;

$K$ — material factor;

$l$ — span of floor, in m, the mean value of the distances, measured between the hopper longitudinal bulkheads along the upper and lower edges of the floor respectively;

$h_1 = \rho(D + h_f) - d + 1.25$, in m, to be taken as $d$ for $h_1 < d$;

$\rho$ — density of spoil, in t/m³, see 14.8.4.2 of this Section;
$D$ — moulded depth, in m;
$h_f$ — vertical distance, in m, measured from the level of the overflow weir to the deck line at side; where the level of the overflow weir is below the deck line at side, the value $h_f$ is negative;
$d$ — draught, in m;
$s_0$ — area of bottom door, in m²;
$f$ — cross sectional area of box keel, in m²;
$p$' — load on the pillar in one floor spacing, in kN, to be calculated according to the requirements of 14.8.8.2 of this Section;
$\alpha$ — coefficient:
for ram bottom door, $\alpha = 2$;
for hinged bottom door, $\alpha = 1$;
for drawer bottom door, $\alpha = 0$.

In other regions, the net cross-sectional area $A$ may be reduced by 20%.

14.8.3.3 Vertical stiffeners are to be fitted to the web of plate floors, spaced not more than $80t$ apart ($t$ being the thickness of web, in mm), and the section modulus $W$ of stiffeners is not to be less than that obtained from the following formula:

$$W = 40slK \quad \text{cm}^3$$

where: $s$ — spacing of stiffeners, in m;
$K$ — material factor;
$l$ — span of stiffener, in m.

The upper edge of floors is to be strengthened by means of a flat bar or rolled section.

14.8.3.4 The thickness of side plates of box floors and the section modulus of stiffeners are to comply with the relevant requirements of this Section for hopper bulkheads.

### 14.8.4 Hopper bulkheads

14.8.4.1 Watertight transverse bulkheads extending from starboard to port are to be provided at both ends of the hopper and the well end.

Both ends of hopper longitudinal bulkheads are to be further extended by means of upper and lower brackets. The upper brackets are to be connected to deck girders or the strength frame ring, while the lower brackets are to be connected to side keelsons or side webs. The length extended is not to be less than two frame spaces, and the height of the brackets is not to be less than 1/4 hopper depth.

14.8.4.2 The thickness $t$ of hopper bulkhead plating is not to be less than that obtained from the following formula, and not less than 8 mm, or not less than 10 mm when a grab is used for loading and unloading:

$$t=3.95s\sqrt{\rho hK}+2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$K$ — material factor;
$\rho$ — density of spoil, in t/m³, $\rho = P/V$;
$P$ — the maximum spoil mass, in t, in hopper at maximum dredging draft;
$V$ — hopper volume, in m³, up to the sill of the uppermost overflow weir;
$h$ — vertical distance, in m, measured from the lower edge of bulkhead plating to the level of the uppermost overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided.

14.8.4.3 The thickness of the lowest plating of hopper bulkheads within the height of $0.1D$ from bottom is not to be less than that of the bottom plating in way, $D$ being the moulded depth.

14.8.4.4 For those portions of hopper bulkheads that are liable to wear, a wear addition of 2 mm to the plate thickness may be considered in design.

14.8.4.5 The section modulus $W$ and sectional moment of inertia $I$ of hopper bulkhead stiffeners are not to be less than those obtained from the following formulae:

$$W=8s\rho hl^2K \quad \text{cm}^3$$
$$I = 2.3Wl/K \quad \text{cm}^4$$

where: $s$ — spacing of stiffeners, in m;
$K$ — material factor;
$\rho$ — density of spoil, in t/m³, the same as that in 14.8.4.2;
$h$ — vertical distance, in m, measured from the mid-span of the stiffener to the level of the uppermost overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided;
$l$ — span of stiffener, in m, or distance between the end of the stiffener and the girder or between

girders where girders are fitted.

Where horizontal stiffeners are fitted, the scantlings of two top stiffeners are to be the same as those of the third one below the deck.

The ends of the stiffeners are to be bracketed. The scantlings of the brackets are to be determined according to 1.2.6 of Section 2, Chapter 1 of this PART.

14.8.4.6 The section modulus $W$ and sectional moment of inertia $I$ of hopper bulkhead girders are not to be less than those obtained from the following formulae:

$$W = 11.7 b \rho h l^2 K \text{ cm}^3$$

$$I = 2.5 W l / K \quad \text{cm}^4$$

where: $b$ — breadth of area supported by girder, in m;

$K$ — material factor;

$\rho$ — density of spoil, in t/m³, the same as that in 14.8.4.2;

$h$ — vertical distance, in m, measured from the mid-span of the girder to the level of the overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided;

$l$ — span of girder, in m.

Where cross ties or braces are provided as required in 14.6.3, Section 6 of this Chapter, the section modulus of hopper bulkhead girders may be reduced by 50%.

14.8.4.7 The web depth of hopper bulkhead girders is not to be less than 2.5 times that of the cut-outs for the passage of bulkhead stiffeners. The breadth of the face plate of the girders is not to be greater than the web depth or 35 times the thickness of the face plate, whichever is the lesser.

14.8.4.8 Hopper bulkhead girders are to be fitted with tripping brackets as required in 1.2.5.4 of Section 2, Chapter 1 of this PART.

14.8.4.9 For trailing suction dredgers, the section modulus of hopper bulkhead stiffeners and girders may be reduced by 10% of that required in 14.8.4.5 and 14.8.4.6.

### 14.8.5 Transverse bulkheads and strength frame ring in side tanks

14.8.5.1 Transverse bulkheads or strength frame rings are to be fitted in the centre plane of hopper plate floors or box floors within side tanks.

The strength frame ring is to be composed of floors, web frames, vertical girders on the hopper longitudinal bulkhead, web beam and/or cross ties (if fitted), and the scantlings of which are to comply with the relevant requirements of this Chapter.

Where the spacing of floors in hopper spaces or of transverse bulkheads or strength frame rings in side tanks exceeds the specified limit, the transverse strength of the hopper region is to be checked.

14.8.5.2 Where the transverse bulkheads in side tanks are watertight or deep bulkheads, the bulkhead plating and stiffeners are to comply with the requirements of Section 12 or Section 13, Chapter 2 of this PART.

14.8.5.3 Where the transverse bulkheads in side tanks are non-watertight, the thickness $t$ of bulkhead plating is not to be less than that obtained from the following formula:

$$t = 0.03L + 5.6 \quad \text{mm}$$

where: $L$ — length of ship, in m.

The section modulus of stiffeners on the bulkhead may be deducted by 40% from that of the stiffeners on the watertight bulkhead. Stiffeners are to be fitted with brackets at both ends. However, the sectional area of the stiffeners supporting longitudinals, girders etc. is also to comply with the requirements of Section 11, Chapter 2 of this PART.

14.8.5.4 The transverse bulkheads in side tanks are to be adequately strengthened in way of the connection with the hopper floors.

### 14.8.6 Hopper web beams and cross beams

14.8.6.1 Web beams or cross beams are to be fitted in the plane of floors in the hoppers (spoil spaces).

14.8.6.2 The section modulus $W$ of hopper web beams is not to be less than that obtained from the following formula:

$$W = (5.75 S h l^2 + 0.102 C F l)\, K \quad \text{cm}^3$$

where: $S$ — spacing of web beams, in m;

$K$ — material factor;

$h$ — pressure head under consideration, in m, to be taken in accordance with 2.8.1.1 of Section 8, Chapter 2 of this PART;

$l$ — span of web beam, in m, the distance between hopper longitudinal bulkheads where no intermediate pillar is fitted, or the distance between the hopper longitudinal bulkhead and the centreline of the intermediate pillar where an intermediate pillar is fitted;

$F$ — maximum mechanical acting force, in kN, when the bottom door is opened or closed;

C — coefficient:

with intermediate pillar, $C = 100K(1 - K)^2$;

without intermediate pillar, $C = 100K(1 - K)$

where $K$ is the ratio of the distance between the point of the acting force and the nearest end to $l$.

14.8.6.3 The section moment of inertia $I$ of the hopper web beam is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: $W$, $l$, $K$ are same as defined in 14.8.6.2 of this Section.

The web depth of hopper web beams is not to be less than twice that of the slot for the passage of longitudinals, and the web thickness is not to be less than 1% of the web depth plus 4 mm.

14.8.6.4 The connection of the hopper web beam to the hopper longitudinal bulkhead is to comply with the requirements of 2.8.7.9 of Section 8, Chapter 2 of this PART.

14.8.6.5 The section modulus $W$ of cross beams is to comply with the requirements of 14.8.6.2 of this Section, where $S$ and $l$ are respectively the face plate breadth and the span of cross beams, in m; where no intermediate pillar is fitted, the span $l$ is the distance between hopper longitudinal bulkheads and where an intermediate pillar is fitted, $l$ is the distance measured from the hopper longitudinal bulkhead to the centreline of the pillar.

Where cross beams support the crane and/or suction pipes, the section modulus is to be increased and is to be determined through calculation. Both ends of the cross beam are to be assumed as rigidly fixed in calculation, and the allowable bending stress is to be taken as $98/K$ N/mm$^2$.

The total net sectional area $A$ of cross beams after deducting openings is not to be less than that obtained from the following formula:

$$A = 2S(C_1D^2 + C_2l^2) + 20)\,K \quad \text{cm}^2$$

where: $S$ — spacing of floors, in m;

$K$ — material factor;

$D$ — moulded depth, in m;

$l$ — span of floor, in m, to be measured in accordance with the requirements of 14.8.3.2 of this Section;

$C_1$, $C_2$ — coefficients, to be taken from Tables 14.8.6.5(1) and (2). Where the value of $C_1D^2 + C_2l^2$ is negative, to be taken as an absolute value.

**Value of $C_1$** **Table 14.8.6.5(1)**

| $d_1/D$ \ $(D + h_f)/D$ | 1. 0 | 1. 1 | 1. 2 | 1. 3 | 1. 4 | 1. 5 |
|---|---|---|---|---|---|---|
| 0. 4 | −0. 1849 | −0. 2637 | −0. 3616 | −0. 4804 | −0. 6222 | −0. 7890 |
| 0. 5 | −0. 1808 | −0. 2596 | −0. 3575 | −0. 4763 | −0. 6181 | −0. 7850 |
| 0. 6 | −0. 1727 | −0. 2515 | −0. 3494 | −0. 4682 | −0. 6100 | −0. 7768 |
| 0. 7 | −0. 1593 | −0. 2381 | −0. 3360 | −0. 4548 | −0. 5966 | −0. 7634 |
| 0. 8 | −0. 1394 | −0. 2182 | −0. 3161 | −0. 4350 | −0. 5767 | −0. 7435 |

**Value of $C_2$** **Table 14.8.6.5(2)**

| $d_1/D$ \ $(D + h_f)/D$ | 1. 0 | 1. 1 | 1. 2 | 1. 3 | 1. 4 | 1. 5 |
|---|---|---|---|---|---|---|
| 0. 4 | 0. 1157 | 0. 1327 | 0. 1497 | 0. 1667 | 0. 1837 | 0. 2007 |
| 0. 5 | 0. 1083 | 0. 1253 | 0. 1423 | 0. 1593 | 0. 1763 | 0. 1933 |
| 0. 6 | 0. 1010 | 0. 1180 | 0. 1350 | 0. 1520 | 0. 1690 | 0. 1860 |
| 0. 7 | 0. 0937 | 0. 1107 | 0. 1277 | 0. 1447 | 0. 1617 | 0. 1787 |
| 0. 8 | 0. 0864 | 0. 1034 | 0. 1204 | 0. 1374 | 0. 1544 | 0. 1724 |

Note: $d_1 = d - 1.25$, in m; $h_f$ — see 14.8.3.2 of this Section; $C_2$ taken from the Table is to be increased by 15% for hinged bottom door.

For $C_1D^2 + C_2l^2 > 0$, the minimum moment of inertia $I$ of cross beams is not to be less than that obtained from the following formula:

$$I = 3Al_1^2/K \quad \text{cm}^4$$

where: $A$ — total sectional area of the cross beam, in cm$^2$;

$K$ — material factor;

$l_1$ — span of cross beam, in m.

Where the floors in the hopper are spaced more than 4 m apart, the scantlings of the cross beams are to be verified by direct calculation, with openings being deducted from the sectional area. The assumptions for the calculation model and the permissible stresses are the same as above.

### 14.8.7 Deck girders and longitudinal cross beams

14.8.7.1 The section modulus $W$ of deck girders or longitudinal cross beams supporting the opening/closing mechanism for the bottom doors is not to be less than that obtained from the following formula:

$$W = (5.3bhl^2 + 1.94Fl)\,K \qquad \text{cm}^3$$

where: $b$ — mean width of deck area supported by the deck girder, in m, for longitudinal cross beams $b$ being the width of the face plate, in m;

$h$ — pressure under consideration, in m, to be determined according to 2.8.1.1 of Section 8, Chapter 2 of this PART;

$K$ — material factor;

$l$ — span of deck girder or longitudinal cross beam, in m;

$F$ — maximum mechanical acting force, in kN, when the bottom door is opened or closed.

### 14.8.8 Pillars

14.8.8.1 Where a box keel is fitted, pillars are, in general, to be fitted for connecting the hopper floors to hopper web beams or cross beams. The scantlings of steel tubular pillars are to comply with the requirements of 2.10.2.1 and 2.10.3.1 of Section 10, Chapter 2 of this PART, except that the wall thickness of which is to be 1 mm more than that obtained from 2.10.3.1 of this PART, and not to be less than 7 mm.

14.8.8.2 The load $P$' supported by the pillar is not to be less than that obtained from the following formula:

$$P' = 7.06abh + \frac{2Fe}{l} + \Delta P \qquad \text{kN}$$

where: $a$ — length of deck area supported by the pillar under consideration, in m, or width of the face plate for cross beams;

$b$ — width of deck area supported by the pillar under consideration, in m, or half the length of the face plate for cross beams;

$h$ — considered pressure head of the deck supported by the pillar under consideration, in m, to be taken according to 2.8.1.1 of Section 8, Chapter 2 of this PART;

$F$ — maximum mechanical acting force, in kN, when the bottom door is opened or closed;

$e$ — distance measured from the point of the mechanical acting force to the end of web beam, in m, when the bottom door is opened or closed;

$l$ — span of the web beam or cross beam, in m;

$\Delta P$ — the acting force on the crane and/or suction pipe supported by pillars, in kN.

### 14.8.9 Continuous coamings

14.8.9.1 Coamings are to have a plate thickness of not less than that obtained from 14.8.4.2 of this Section for the longitudinal bulkhead strakes in hoppers.

Horizontal stiffeners of the coaming are to be spaced apart not more than 80 times the plate thickness of the coaming for the lower panel of plating, and not more than 65 times the plate thickness of the coaming for the upper panel of plating. The moment of inertia $I$ of the horizontal stiffener is not to be less than that obtained from the following formula:

$$I = 2Al^2 \qquad \text{cm}^4$$

where: $A$ — total sectional area of the horizontal stiffener with attached plating, in cm²;

$l$ — spacing of coaming brackets, in m.

14.8.9.2 The coamings are to be extended beyond both ends of the hopper for a distance of at least 1.5 times the coaming height in general.

14.8.9.3 The upper edge of the coaming is to be stiffened by a fabricated flange, or an equivalent structure capable of achieving a good rigidity of the coaming.

14.8.9.4 The coaming brackets are to be arranged in way of each deck transverse. The thickness of brackets is to be equal to that of the coaming plating. The width of the lower end of brackets is not to be less than 1/3 times the height of the coaming plating. Where the coaming and the hopper longitudinal bulkhead are not in the same plane, the breadth of the lower end of brackets is not to be less than twice the distance between the hopper longitudinal bulkhead and the coaming, and supporting brackets having a

thickness equal to that of the coaming are to be fitted within the hopper in the same plane of coaming brackets. The brackets are to have a flange or face plate with a width 10 times their thickness.

# Section 9 SPLIT HOPPER DREDGERS AND BARGES

### 14.9.1 General requirements

14.9.1.1 This Section applies to self-propelled or non-self-propelled steel split hopper barges and dredgers with a single deck. Those not covered in this Section are to comply with the other applicable requirements of this Chapter.

14.9.1.2 A chain locker and a chain are usually to be provided on each half hull. For split hopper barges only a single windlass may be provided on one of the half hulls. However, an appropriate guide gear is to be fitted so as to retract and release conveniently the chain on the other half hull.

Unmanned split hopper barges may be provided with only a single bower anchor. The length of the chain may be half the length as specified.

14.9.1.3 Rudder and steering gear are to be provided on each half hull, and an automatic system for operating two rudders simultaneously is to be provided.

14.9.1.4 Where the hopper extends beyond 0.4*L* amidships, the thickness of shell plating and deck plating amidships is to extend from hopper end bulkheads for two frame spaces and have a gradual transition fore and aft.

14.9.1.5 Shell plating and longitudinals in bilge area a re to be sufficiently strengthened.

14.9.1.6 In addition to the grades of steel required in 1.3.2 of Section 3, Chapter 1 of this PART, grade D steel is to be adopted for the plates bearing high stresses (reaction forces of hinges, hydraulic installations, load-bearing plates, etc.) and having a thickness greater than 20 mm, and grade E steel is recommended where the thickness of such plates is greater than 40 mm.

14.9.1.7 For solid floors in each half hull, *B* in the formula may be taken as the breadth of the half hull when it is calculated according to 2.5.4.1, Section 5, Chapter 2 of this PART.

### 14.9.2 Longitudinal strength

14.9.2.1 The midship section modulus of split hopper barges and dredgers of 65 m or over in length is to comply with the requirements of 14.2.2.1(1), Section 2 of this Chapter. The semi-sectional area of the midship strength deck of split hopper barges and dredgers less than 65 m in length is to comply with the requirements of 14.4.2.1, Section 4 of this Chapter.

14.9.2.2 For all split hopper barges and dredgers, the longitudinal strength of half hulls is to be checked for transit and dredging conditions, taking the influence of departure and arrival into account.

14.9.2.3 The longitudinal bending stress at any point of the cross section of half hulls within 0.4*L* amidships is to be obtained from the following formula, and not to be greater than 175/*K*, in N/mm², where *K* is material factor:

$$\sigma = \left( \frac{M_X}{I_X} Y - \frac{M_Y}{I_Y} X \right) \times 10^5 \quad \text{N/mm}^2$$

where: $M_X$, $M_Y$ — bending moment about main axis of inertia, in kN · m, to be calculated in accordance with 14.9.2.4;

$X$, $Y$ — coordinate value of the considered point in coordinate system $GXY$ of main axis of inertia, in m, see Figure 14.9.2.3;

$I_X$, $I_Y$ — moment of inertia about main axis of inertia, in cm$^4$.

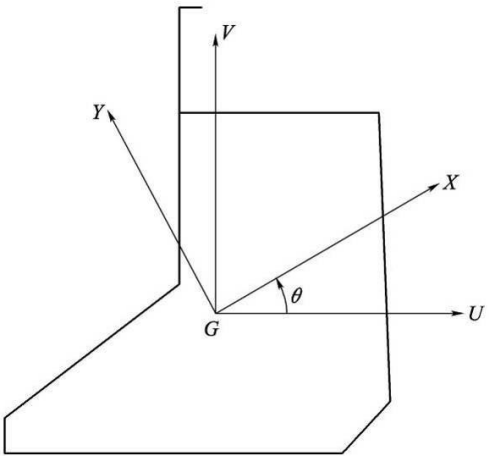



**Figure 14.9.2.3**

14.9.2.4 Bending moments $M_X$ and $M_Y$ about the main axis of inertia ($GX$, $GY$) of half hulls are to be obtained from the following formulae:

$$M_X = M_u \cos\theta + M_v \sin\theta \quad \text{kN} \cdot \text{m}$$

$$M_Y = -M_u \sin\theta + M_v \cos\theta \quad \text{kN} \cdot \text{m}$$

where: $M_u$, $M_v$ — vertical bending moment and horizontal bending moment of section, in kN·m, respectively.

14.9.2.5 The vertical bending moment acting on half hulls in the midship area is to be obtained from the following formulae:

For transit condition: $M_u = 0.5(M_s + M_{wv})$ kN · m

For dredging condition: $M_u = 0.5(M_{sd} + M_{wv})$ kN · m

where:

$M_s$, $M_{sd}$ — the maximum vertical still water bending moment under corresponding conditions, in kN · m, hogging moment being positive while sagging moment being negative;

$M_{wv}$ — vertical wave bending moment, to be calculated in accordance with 2.2.3.1 of Section 2, Chapter 2 of this PART.

14.9.2.6 The horizontal bending moment acting on half hulls in the midship area is to be determined by the following formulae:

For transit condition: $M_v = M_{sH} + M_{wH}$ kN · m

For dredging condition: $M_v = M_{sHd} + M_{wH}$ kN · m

where: $M_{wH}$ — horizontal wave bending moment, in kN · m, the positive and negative values being the same as those of $M_{sH}$ or $M_{sHd}$, calculated in accordance with the following formula:

$$M_{wH} = \pm 0.2\, L^{2.25}(d + 0.3B)C_b \quad \text{kN} \cdot \text{m}$$

where: $L$ — length of ship, in m;

$B$ — breadth of ship, in m;

$d$ — draft under corresponding condition, in m;

$C_b$ — block coefficient under corresponding condition;

$M_{sH}$ — horizontal still water bending moment under transit condition, in kN · m, generally $M_{sH} = 0$;

$M_{sHd}$ — horizontal still water bending moment under dredging condition, in kN · m. Where side edge is compressed, the horizontal still water bending moment is positive; where side edge is tensed, the horizontal still water bending moment is negative, calculated in accordance with the following formula:

$$M_{sHd} = \pm 0.125\, PL_p\,(2L_d - L_p) \quad \text{kN} \cdot \text{m}$$

where: $L_p$ — length of hopper, in m, see Figure 14.9.2.6;

$L_d$ — spacing of deck hinges, in m, see Figure 14.9.2.6;

$P$ — horizontal load per unit length, in kN/m, calculated in accordance with the following formula:

$$P = 4.9\rho\,(h_1 - a)^2 - 5.0(d - a)^2$$

where: $\rho$ — density of spoil, in t/m³, the same as that in 14.8.4.2;

$h_1$ — maximum height of spoil loaded above baseline, in m;

$a$ — height of bottom sealing installation, in m;

$d$ — draft under corresponding condition, in m.

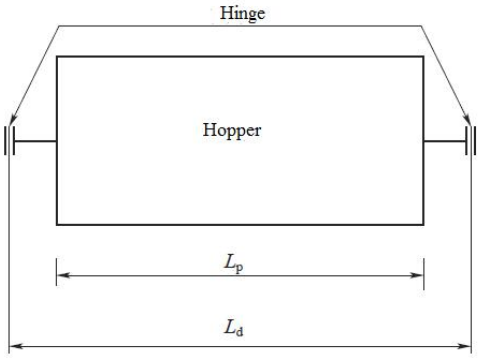



**Figure 14.9.2.6**

### 14.9.3 Deck hinges and hydraulic installations

14.9.3.1 The hydraulic installations connecting two half hulls is to have sufficient power so as to ensure that the half hulls can be opened and closed efficiently under any predicted sea conditions and that the half hulls will not be accidentally parted due to motion and vibration of the ship.

14.9.3.2 Local structures in way of connection to deck hinges and hydraulic installations are to be sufficiently strengthened, and are to efficiently transmit the load to the hull structure.

14.9.3.3 The scantlings of the members connecting deck hinges and hydraulic installations to two half hulls are to be determined by direct calculation. The load acting on such members is to be determined in accordance with the appropriate combination of predicted maximum static load and dynamic load under different design conditions.

14.9.3.4 The combined force $F_h$ born by deck hinges under different design conditions is to be calculated in accordance with the following formula:

$$F_h = \sqrt{(F_{sh} + F_{dh})^2 + F_{dv}{}^2} \quad \text{kN}$$

where: $F_{sh}$ — horizontal static force of deck hinges, in kN, to be calculated in accordance with 14.9.3.6(1) of this Section;

$F_{dh}$ — horizontal dynamic force of deck hinges, in kN, to be calculated in accordance with 14.9.3.7 of this Section;

$F_{dv}$ — vertical dynamic force of deck hinges, in kN, to be calculated in accordance with 14.9.3.7 of this Section.

14.9.3.5 The horizontal force $F_r$ born by hydraulic installations under different design conditions is to be calculated in accordance with the following formula:

$$F_r = F_{sr} + F_{dr} \quad \text{kN}$$

where: $F_{sr}$ — horizontal static force of hydraulic installations, in kN, to be calculated in accordance with 14.9.3.6(2) of this Section;

$F_{dr}$ — horizontal dynamic force of hydraulic installations, in kN, to be calculated in accordance with 14.9.3.7 of this Section.

14.9.3.6 The horizontal static force of deck hinges and hydraulic installations is to be determined as follows:

(1) Horizontal static force $F_{sh}$ of hinges:

$$F_{sh} = 0.5\left[F_w - F_s + 2(1 - \frac{h_4}{h_5})F_{sr} + \frac{M}{h_5}\right] \quad \text{kN}$$

where: $F_w$ — external still water pressure within hopper, in kN, to be calculated by the following formula:

$$F_w = 5.0(d - a)^2 L_p$$

$F_s$ — horizontal pressure of spoil, in kN, to be calculated by the following formula:

$$F_s = 4.9\rho(h_1 - a)^2 L_p$$

$\rho$, $h_1$, $d$, $a$, $L_p$ — the same as those in 14.9.2.6;

$F_{sr}$ — horizontal action force of hydraulic installations, in kN, to be determined according to (2) below;

$M$ — moment, in kN · m, positive for opened half hull and negative for closed hull, determined by the following formula:

$$M = F_s h_2 - F_w h_3 + \Delta b_1 - W_l b_2 - W_s b_3$$

$h_2$ — vertical distance from horizontal pressure of spoil to hinge point, in m;

$h_3$ — vertical distance from external still water force to hinge point, in m;
$h_4$ — vertical distance from horizontal force of hydraulic installation to hinge point, in m;
$h_5$ — vertical distance from deck hinges to baseline, in m;
$\Delta$ — still water buoyancy of loaded half hull, in kN;
$W_l$ — gravity of empty half hull, in kN;
$W_s$ — gravity of half hull spoil, in kN;
$b_1$, $b_2$, $b_3$ — horizontal distance from $\Delta$, $W_l$, $W_s$ to hinge point respectively. See Figure 14.9.3.6.

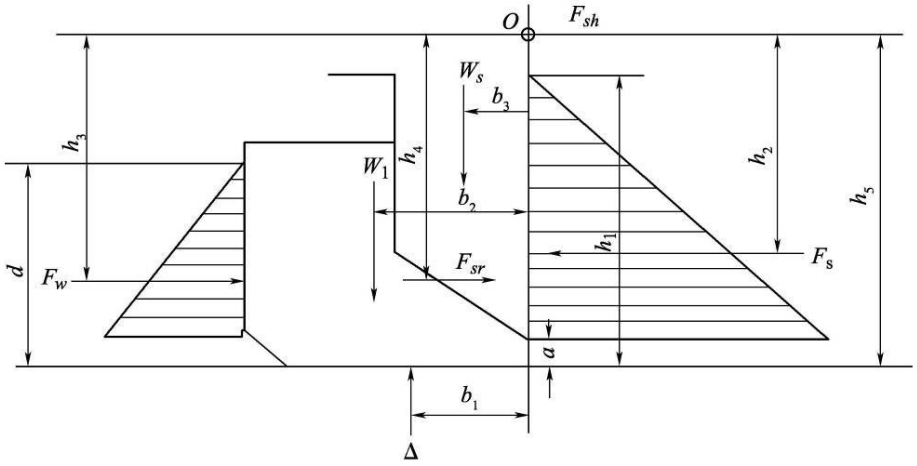



**Figure 14.9.3.6**

(2) The horizontal static force $F_{sr}$ of hydraulic installations is equal to the pressure $F_P$ acting on the end surface of the hydraulic cylinder piston, in kN, and its moment about the hinge point is to be equal to or more than the opening moment $M$ so as to ensure the closure of two half hulls, i.e.:

$$F_{sr} = F_p \geq \frac{M}{2h_4} \quad \text{kN}$$

14.9.3.7 The dynamic load induced by the ship's motions in waves and acting on deck hinges and hydraulic installations is to be obtained from the dynamic calculation and statistic analysis in accordance with sea conditions for predicted operations. Where the significant wave height is no more than 3 m in sea conditions for predicted operations, the dynamic load may also be calculated in accordance with the following formulas:

Horizontal dynamic force of deck hinges: $F_{dh} = 0.28 f B^2 L$ kN

Vertical dynamic force of deck hinges : $F_{dv} = 0.055 f B^2 L^2 / d$ kN

where: $L$——ship length, in m;
$B$——ship width, in m;
$d$——distance between deck hinges, in m;
$f$——coefficient, taken $f$=1.5.

14.9.3.8 The formulae in 14.9.3.6 of this Section are only applicable to such condition where one deck hinge and one hydraulic installation are respectively fitted at both ends of the hopper. Where the number of hinges and/or hydraulic installations are not the same, the calculation regarding systems of static and dynamic forces acting on the hull is required.

14.9.3.9 The scantlings of different parts of hinges are to be obtained as follows:

(1) The diameter $d$ of the hinge pin is not to be less than that obtained from the following formulae:

$$d_1 = 54\sqrt{\frac{F}{R_{eH}}} \quad \text{mm}$$

$$d_2 = 13.2\sqrt[3]{\frac{F(2a - t_{2c})}{R_{eH}}} \quad \text{mm}$$

where: $F$ — resultant force of hinges, in kN, to be calculated in accordance with 14.9.3.4 of this Section;
$a$ — distance, in mm, between inner edges of eye plates at both sides or between inner edges of bushes of eye plates at both sides;
$t_{2c}$ — length of contact, in mm, between centre eye plate or its bush and hinge pin;
$R_{eH}$— yield strength of hinge pin material, in N/mm².

(2) Eye plates are to comply with the following:

For centre eye plates: $b_{2c}t_{2c} + b_{1c}t_{1c} \geq \dfrac{2500\ F}{R_{eH}}$ mm$^2$

For side eye plates: $b_{2s}t_{2s} + b_{1s}t_{1s} \geq \dfrac{1250\ F}{R_{eH}}$ mm$^2$

where: $F$ — the same as that in (1);

$R_{eH}$— yield strength of the material of eye plates, in N/mm²;

$b_{1c}$, $b_{2c}$, $b_{1s}$, $b_{2s}$, $t_{1c}$, $t_{2c}$, $t_{1s}$, $t_{2s}$, — see Figure 14.9.3.9.

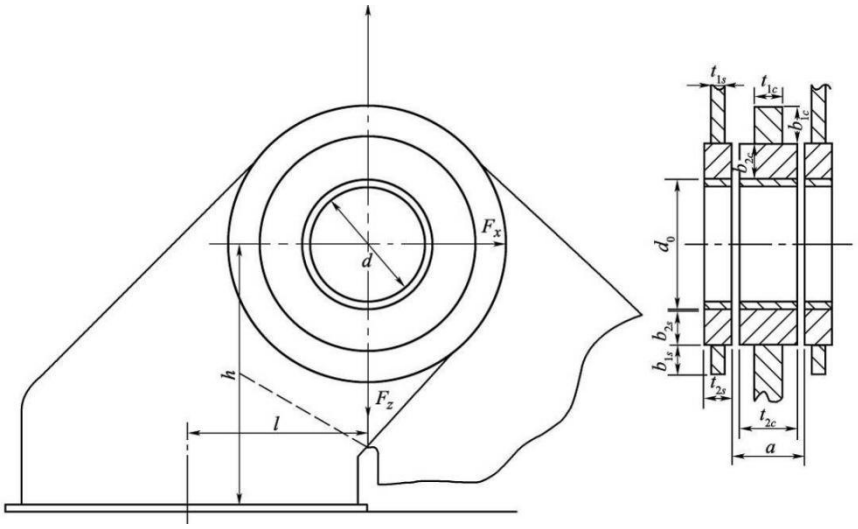



**Figure 14.9.3.9**

(3) The section of connection of centre eye plate and side eye plates to deck is to comply with the following formula:

$$\left(\frac{F_z}{A} + \frac{F_x h + F_z l}{W}\right) \times 10^3 \leq 0.6R_{eH} \quad \text{N/mm}^2$$

where: $F_x$ — horizontal force of hinges, in kN, to be obtained from the following formula:

$$F_x = F_{sh} + F_{dh}$$

$F_z$ — vertical force of hinges, in kN, to be obtained from the following formula:

$$F_z = F_{dv}$$

$h$ — vertical distance from pintle centre to deck, in mm;

$l$ — horizontal distance from centre of the hinge pin to sectional neutral axis, in mm;

$A$ — sectional area, in mm²;

$W$ — section modulus, in mm³;

$R_{eH}$ — yield strength of the material of eye plates, in N/mm².

### 14.9.4 Hinges of deckhouses

14.9.4.1 The load acting on deckhouses is to be determined in accordance with the loading condition and movement of the ship.

14.9.4.2 The force born by deckhouses may be divided into three component forces of $F_x$, $F_y$ and $F_z$, as shown in Figure 14.9.4.2, where $OX$ is the central axis of rolling; $F_x$, $F_y$ and $F_z$ are acting at the centre of gravity of deckhouses.

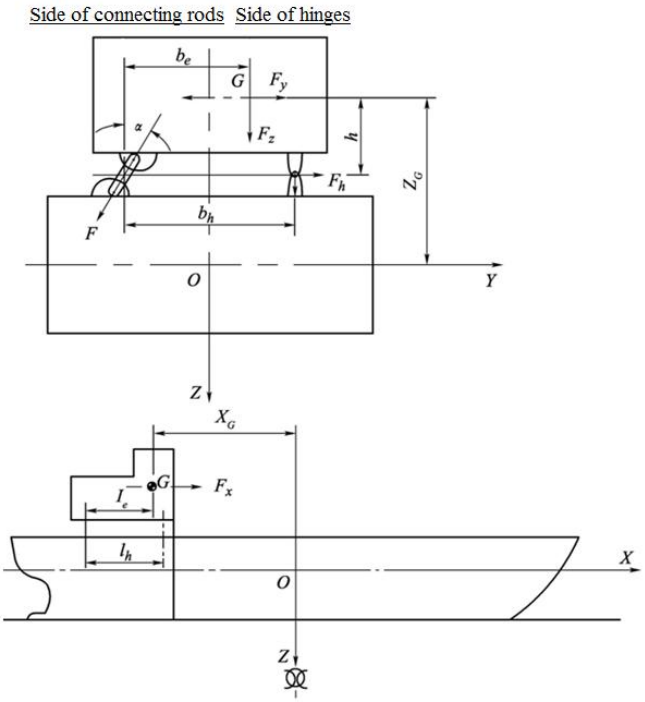



**Figure 14.9.4.2**

14.9.4.3 The distance from the central axis of rolling to baseline may be taken as the lesser of $\frac{D}{4}+\frac{d}{2}$ and $\frac{D}{2}$ ,where $D$ and $d$ are moulded depth and draft respectively, in m.

14.9.4.4 The longitudinal and transverse component forces $F_x$, $F_y$ parallel to deck and the vertical component force $F_z$ normal to deck are to be obtained from the following formulae:

$$F_x = Mg\,(0.19 + 0.026\,Z_G) \quad \text{kN}$$
$$F_y = Mg\,(0.5 + 0.039\,Z_G) \quad \text{kN}$$
$$F_z = Mg\,(1.17 + 0.026\,X_G) \quad \text{kN}$$

where: $M$ — mass of deckhouses, in t;
$Z_G$ — vertical distance from the center of gravity of deckhouses to $OXY$ plane, in m;
$X_G$ — horizontal distance from the center of gravity of deckhouses to $OYZ$ plane, in m;
$g$ — gravity acceleration, in m/s².

14.9.4.5 Where longitudinal load-bearing plates are provided to both half hulls, it may be assumed that the transverse component force $F_y$ and the vertical component force $F_z$ be born by hinges of deckhouses, and that the longitudinal component force $F_x$ be born by longitudinal load-bearing plates. Otherwise, the hinges of deckhouses are also to bear the longitudinal component force $F_x$.

14.9.4.6 The forces born by the hinges of deckhouses are to be obtained by solving an equilibrium equation of force systems, according to the type and position of hinges and the actual position of the center of gravity of deckhouses.

14.9.4.7 Where the hinges of deckhouses are composed of two hinges and two end-hinged connecting rods, as shown in Figure 14.9.4.2, the forces born by the hinges are to be obtained by the following formulae:

For axial force $F$ on connecting rods:

$$F = \frac{l_e}{l_h \cos\alpha}\left[F_y \frac{h}{b_h} + F_z\left(1 - \frac{b_e}{b_h}\right)\right] \quad \text{kN}$$

For transverse force $F_h$ on hinges:

$$F_h = \frac{l_e}{l_h}\left[F_y\left(1 - \frac{h}{b_h}\tan\alpha\right) + F_z\left(1 - \frac{b_e}{b_h}\right)\tan\alpha\right] \quad \text{kN}$$

For vertical force $F_v$ on hinges:

$$F_v = \frac{l_e}{l_h}\left(F_y \frac{h}{b_h} + F_z \frac{b_e}{b_h}\right) \quad \text{kN}$$

For horizontal force $F_c$ on each load-bearing plate:

$$F_c = \frac{1}{n_c} F_x \quad \text{kN}$$

where: $F_x$, $F_y$, $F_z$ — component forces acting on the center of gravity of deckhouses, in kN, to be determined in accordance with 14.9.4.4 of this Section;

$\alpha$ — the angle between the centreline of connecting rod and a vertical line, in degrees.;

$l_e$ — longitudinal distance from the center of gravity of deckhouses to the farther hinge, in m;

$b_e$ — transverse distance from the center of gravity of deckhouses to the vertical line at the centre of connecting rod, in m;

$h$ — vertical distance from the center of gravity of deckhouses to the horizontal centreline of hinges;

$b_h$ — transverse distance between hinge centre and connecting rod centre;

$l_h$ — longitudinal distance between the centres of fore and aft hinges, in m;

$n_c$ — number of load-bearing plates.

14.9.4.8 The scantlings of different parts of hinges of deckhouses are to be determined in accordance with 14.9.3.9 of this Section.

# Section 10 MISCELLANEOUS

### 14.10.1 Bulwarks, guardrails and freeing ports

14.10.1.1 In open hopper dredgers or barges, bulwarks are not to be fitted in way of the hopper regions, but guardrails or reliable slip arrangements are to be provided. For dredgers fitted with bulwarks, freeing ports with adequate areas are to be fitted throughout the whole length of bulwarks.

### 14.10.2 Fenders

14.10.2.1 Dredgers and hopper barges in accordance with their operation characteristics are generally to be fitted with fenders along the deck edges throughout the ship's length. Dredgers designed to work in conjunction with hopper barges are to be fitted also with fenders extending down to their lowest normal operating waterline. Vertical fenders with appropriate spacing are also to be fitted between two fenders. The thickness of fenders may be taken as the thickness of the side shell plating at 0.4$L$ amidships. Stiffeners are to be fitted inside the fenders.

### 14.10.3 Overflows

14.10.3.1 The cutting of overflow discharge trunk openings in the sheer strake is to be avoided wherever practicable. In ships over 65 m in length, hopper overflow discharge trunk openings are not to be cut within 800 mm of the upper edge of the sheer strake. They are to have corner radii of not less than 150 mm, and suitable compensation is to be arranged. In no case is a discharge trunk to pierce the sheer strake in way of discontinuities such as breaks of superstructure.

### 14.10.4 Watertight trunk

14.10.4.1 Watertightness is to be kept around dredging pumps, within local range of holds in way of suction pipes and suction of trailing suction dredgers, penetrating through the hull.

### 14.10.5 Cofferdams

14.10.5.1 Ladder wells of bucket dredgers are to be isolated by cofferdams, the extent and widths of which are to be sufficient to contain any damage to the well side bulkheads or bottom shell plating that could result from the impact of large objects brought up in the dredge buckets. The cofferdams are to be accessible.

### 14.10.6 Supporting structures and seats of operating equipment

14.10.6.1 The local supporting structures connected with equipment members and foundations, as well as the seats of operating equipment are to have sufficient strength where necessary, the strength is to be checked.

14.10.6.2 Where direct calculation for check is applied, the model and strength criteria may refer to

3.7.2.5 and 3.7.2.6 of Chapter 3 of this PART. The loads are to be applied based on the working loads of equipment (e.g. working supporting loads of hydraulic winch), and the strength criteria may refer to Table 3.7.3.12 of Chapter 3 of this PART.

# CHAPTER 15 SEMI-SUBMERSIBLE VESSELS

## Section 1 GENERAL PROVISIONS

### 15.1.1 Application

15.1.1.1 This Chapter applies to the semi-submersible vessels intended for the carriage of ships, offshore installations or other massive goods.

15.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

### 15.1.2 Definitions

15.1.2.1 **Semi-submersible vessel** means a ship, designed to load and unload cargoes, which is capable of being in a semi-submerged condition, with large open weather cargo deck and generally fitted with a forward or aft high superstructure or deckhouse or pontoon.

15.1.2.2 **Semi-submerged condition** means any condition in which the lifting cargo deck is submerged and reserve buoyancy is provided by the superstructure or deckhouse or pontoon only.

15.1.2.3 **Lifting cargo deck** means an open weather deck which is used for the carriage of goods and is submerged during loading/unloading operation.

15.1.2.4 **Maximum submerged depth** means a maximum draft to which the vessel is allowed to be submerged in semi-submerged operation conditions.

### 15.1.3 Drawings and information

15.1.3.1 In addition to those stipulated in Section 1, Chapter 2 of this PART, the following drawings and information are to be submitted for reference:

(1) Hydrostatic curves, lifting and submersing curves;

(2) Operating manual.

## Section 2 STRUCTURAL STRENGTH

### 15.2.1 General requirements

15.2.1.1 All ballast tanks are to be provided with air pipes, the diameters of which are to be in compliance with the relevant provisions of the Rules. A certain number of manholes are to be made at the appropriate locations in longitudinal and transverse strength members of all ballast tanks so that each part of the tanks can be easily reached. At the same time, they are effective for ventilation when the tanks are empty.

15.2.1.2 Where a non-self-propelled semi-submersible barge is to be towed, the calculation of towing strength is to be made, and consideration is to be given to the arrangement of towing equipment and relevant structural strengthening.

15.2.1.3 General tensile steel or high tensile steel adopted for hull structure of semi-submersible vessels is to be in compliance with the relevant provisions of the Rules.

15.2.1.4 Where direct calculation or other commonly used empirical formulae are applied to determine the scantlings of each member, the relevant calculations and calculation assumptions and descriptions are to be submitted for examination.

### 15.2.2 Longitudinal strength

15.2.2.1 The longitudinal strength is to meet the following requirements:

(1) The longitudinal strength is to meet the requirements of Chapter 2 of this PART under sea-going condition;

(2) For typical operation conditions of the semi-submersible vessel, longitudinal wave load is to be taken 50% of the value required in 2.2.3 of Chapter 2 of this PART;

(3) For loading and unloading conditions in harbor under mooring condition, longitudinal wave load is to be taken 20% of the value required in 2.2.3 of Chapter 2 of this PART;

(4) Possible or assumed most critical operation condition is also to be considered.

15.2.2.2 The minimum section modulus $W_0$ at deck and keel within at least $0.25L$ amidships of semi-submersible vessel is to meet the requirements of 2.2.5.1 of Chapter 2 of this PART.

15.2.2.3 The structural members considered in the calculation of the section modulus in respect to longitudinal strength are to be longitudinally continuous within $0.4L$ amidships. However, the crane trail is not to be considered in section modulus calculation.

15.2.2.4 For non-self-propelled semi-submersible barges designed for operation in three types of navigation zones or port, the loads and design conditions with respect to longitudinal strength in operation condition may be calculated in accordance with the relevant requirements of CCS Rules and Regulations for the Construction and Classification of Floating Docks.

### 15.2.3 Transverse strength

15.2.3.1 The transverse strength is to be checked for the typical transverse structures throughout the whole vessel.

15.2.3.2 The conditions of the transverse strength calculation are to cover the typical operation conditions of the semi-submersible vessel, including the assumed most critical operation condition.

15.2.3.3 The following loads are to be taken into account in the check of transverse strength:

(1) self-weight of the semi-submersible vessel including supporting blocks;

(2) maximum weight of objects to be carried;

(3) external hydrostatic pressure at a given draught;

(4) internal hydrostatic pressure due to the level of evenly distributed ballast associated with the draught as in (3) when lifting at maximum capacity.

15.2.3.4 The bending stresses are not to exceed $170/K$, in N/mm², the shear stresses are not to exceed $95/K$, in N/mm² and the combined stress at any point is not to exceed $180/K$, in N/mm² ($K$ being the material factor).

### 15.2.4 Local strength

15.2.4.1 The local strength under sea-going condition is to be calculated according to the relevant requirements of Section 13, Chapter 2 of this PART, and the strength under the lifting and submersing conditions (including the process of adjusting the ballast water level) is to be calculated in accordance with the requirements of this Section.

15.2.4.2 The thickness of boundary plating of ballast water tanks, oil tanks, fresh water tanks, bilge tanks, empty tanks, etc., is not to be less than the value obtained from the following formula:

$t = t_0 + 2.5$ mm, and not to be less than 7.5 mm

where: $t_0 = 3.95s\sqrt{\rho h K}$, $t_0$ is also to be multiplied by $1.1 - \frac{s}{2.5l}$ for $l/s<4$;

$K$ — material factor;

$s$ — spacing of stiffeners, in m;

$\rho$ — density of liquid, in t/m$^3$, taken as not less than 1.025 for calculation;

$h$ — calculated pressure head, in m, see Table 15.2.4.2, to be measured from the lower edge of plate;

$l$ — span of stiffener, in m.

**Table 15.2.4.2**

| Position of members | Pressure head $h$ (m) |
|---|---|
| 1. Boundary plating subjected to external hydrostatic pressure and internal hydrostatic pressure on both sides, such as shell plating of wing tanks, etc. | $h_1$: The maximum differential head in the position obtained from the lifting and submersing curve |
| 2. Boundary of ballast water tank | $h_2$: The maximum differential head between two sides, not less than 3.5 m |
| 3. Watertight boundary of empty hold | The greatest of the following heads:<br>$h_1$: The maximum differential head in the position obtained from the lifting and submersing curve (if applicable)<br>$h_2$: The maximum differential head between two sides, not less than 3.5 m (if applicable)<br>$h_3$: The vertical distance from the considered point to the deepest submersing water level, not less than 3.5 m<br>$h_4$: The differential head in the deepest submerging position obtained from the lifting and submerging curve |
| 4. Ballast tank where compressed air is used to discharge water (if applicable) | The greatest of the following heads:<br>$h_1$: The maximum differential head in the position obtained from the lifting and submersing curve (if applicable)<br>$h_2$: The maximum differential head between two sides, not less than 3.5 m (if applicable)<br>$h_3$: The vertical distance from the considered point to the deepest submersing water level, not less than 3.5 m<br>$h_4$: The differential head in the deepest submerging position obtained from the lifting and submerging curve<br>$h_5$: Water head equivalent to the compressed air, not less than 3.5 |

| Position of members | Pressure head $h$ (m) |
|---|---|
| | m |

15.2.4.3 For structural members subjected to lateral pressure on tank boundary plating as defined in 15.2.4.2 of this Section, such as bulkhead stiffeners, longitudinals, beams and ordinary frames, etc., the minimum section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 7shl^2K \qquad \text{cm}^3$$

where:

$s$ — spacing of stiffeners, in m;
$K$ — material factor;
$l$ — span of stiffener, in m;
$h$ — calculated pressure head, in m, see Table 15.2.4.2, to be taken the middle point of span.

15.2.4.4 The section modulus $W$ of primary members (such as transverses, web frames, girders, etc.) is not to be less than:

$$W = 7bhl^2K \qquad \text{cm}^3$$

where:

$b$ — breadth of supporting, in m, taken as the spacing of primary structural members;
$K$ — material factor;
$l$ — the considered span, in m;
$h$ — calculated pressure head, in m, see Table 15.2.4.2, to be taken the middle point of span.

15.2.4.5 The thickness of non-watertight pillar bulkhead plating and the scantlings of stiffeners may be determined in accordance with the relevant requirements of the Rules, provided that the loading $P$ is taken as the actual load supported by the pillars.

15.2.4.6 The sectional area, plate thickness and end reinforcement of cross ties are to be in accordance with the relevant requirements of Section 10, Chapter 2 of this PART, provided that the load $P$ is taken as follows:

$$P = 9.8shl \qquad \text{kN}$$

where:

$s$ — spacing of cross ties, in m;
$h$ — maximum differential head, in m, to be measured from the lower edge of cross ties to the water level at maximum differential head;
$l$ — vertical midspan-to-midspan distance between two girders immediately over and under the cross tie, in m.

# CHAPTER 16 ORE CARRIERS

## Section 1 GENERAL PROVISIONS

### 16.1.1 Application

16.1.1.1 This Chapter applies to scantlings and structural arrangement of single deck ore carriers with machinery aft, having two longitudinal bulkheads and a double bottom throughout the cargo region intended for the carriage of ore cargoes in the centre holds. A typical cross section of such ore carriers is shown in Figure 16.1.1.1.

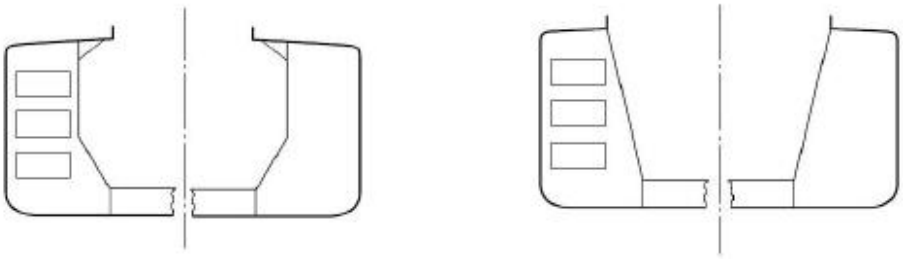


**Figure 16.1.1.1**

16.1.1.2 The loading manual and loading instrument of ore carriers are to comply with the requirements of Section 7, Chapter 8 of this PART.

16.1.1.3 The requirements of Sections 3 and 4 of this Chapter are only applicable to the cargo hold area. Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

### 16.1.2 Ship arrangement and structural configuration

16.1.2.1 The bottom within cargo area and the strength deck outside the line of hold openings are to be framed longitudinally, and the strength deck inside the line of hold openings is to be framed transversely.

16.1.2.2 The transverse watertight bulkheads in centre holds within the cargo region are to be located in the same plane with those in wing tanks as far as practicable, otherwise arrangements are to be made to ensure the continuity of transverse strength. However, the form of construction used for transverse watertight bulkheads in centre holds may be different from that used in wing tanks.

16.1.2.3 Strength frame rings, transverse watertight bulkheads and wash bulkheads, which may be fitted in wing tanks within the cargo region, are to be in the same plane with bottom floors of center holds.

16.1.2.4 Where necessary, the bottom between strength frame rings may be fitted with intermediate floors.

### 16.1.3 Direct strength calculation and fatigue strength assessment for hull structure

16.1.3.1 For ore carriers of 150 m and over in length, direct strength calculation in respect to primary members of the hull is to be carried out in accordance with the requirements of CCS Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers.

16.1.3.2 For ore carriers of 150 m and over in length, fatigue strength assessment in respect to the following locations within the cargo region is to be carried out in accordance with the requirements of CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse web frames;
(2) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse bulkheads;
(3) connections of longitudinal bulkheads to inner bottom plates;
(4) connections of inner bottom plates to lower stools;
(5) longitudinal bulkhead knuckles (if any).

16.1.3.3 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of springing and whipping on hull structure fatigue strength. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

## Section 2 LONGITUDINAL STRENGTH

### 16.2.1 General requirements

16.2.1.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this

PART.

16.2.1.2 Where the hold deck opening is large, the longitudinal strength in respect to a combination of bending moment and torque is to be checked in accordance with the requirements of Section 10, Chapter 7 of this PART, with the torque of cargo being taken as zero in general.

### 16.2.2 Ultimate strength of hull girder

16.2.2.1 The ultimate bending capacity of any transverse section of hull girder during navigation is to comply with the following requirements.

(1) The vertical ultimate bending capacity of hull girder is to comply with the following criteria:

$$\gamma_s \overline{M}_s + \gamma_w M_w \le \frac{M_U}{\gamma_R}$$

where: $\overline{M}_s$ — permissible still water bending moment, in kN·m;

$M_w$ — wave bending moment, in kN·m;

$M_U$ — vertical ultimate bending capacity of hull girder, in kN·m;

$\gamma_s$, $\gamma_w$, $\gamma_R$ — partial safety factors, to be taken as:

$\gamma_s = 1.0$;

$\gamma_w = 1.2$;

$\gamma_R = \gamma_M \cdot \gamma_{DB}$;

where:

$\gamma_M$ — partial safety factor, covering material, geometric and strength prediction uncertainties, to be taken as: $\gamma_M = 1.05$;

$\gamma_{DB}$ — partial safety factor, covering the effect of double bottom bending, to be taken as:

$\gamma_{DB} = 1.10$ for hogging condition;

$\gamma_{DB} = 1.0$ for sagging condition.

(2) Curve $M$-$\chi$

The ultimate bending capacities of a hull girder transverse section $M_U$, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity $M$ versus the curvature $\chi$ of the transverse section considered.

The curvature $\chi$ is positive for hogging condition and negative for sagging condition.

The curve $M$-$\chi$ is to be obtained by means of an incremental-iterative approach in accordance with Appendix 5, Chapter 7 of this PART.

(3) The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, and the standard diminution thickness given in Table 16.2.2.1 is to be deducted in calculation.

**Standard thickness deduction** **Table 16.2.2.1**

| Position | | Standard thickness deduction (mm) |
|---|---|---|
| Within 1.5 m below weather deck | One side connected to ballast water | 1.0 |
| | Two sides connected to ballast water | 2.0 |
| Elsewhere | | 1.0 |

16.2.2.2 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of whipping on hull girder ultimate strength. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

## Section 3 HULL FRAMING

### 16.3.1 Double bottom

16.3.1.1 Unless provided otherwise in this Section, the structural arrangement and scantlings of double bottom are to comply with the relevant requirements of Section 6, Chapter 2 and Section 2, Chapter 8 of this PART. For ore carriers of 230 m and over in length, however, plate floors may be spaced not more than 2.8m apart.

16.3.1.2 The width and depth of the double bottom in way of centre holds are to comply with the strength requirements of this Chapter and in addition, the requirements for stability in loaded conditions.

16.3.1.3 Where the proposed depth of the double bottom exceeds 1.5 times the minimum depth required in Section 6 of Chapter 2 of this PART, the scantlings of the stiffeners on floors and girders are to be

increased and the buckling of stiffeners, floors and girders is to be checked.

16.3.1.4 The scantlings of the stiffeners of watertight floors and girders in double bottom are to comply with the requirements for the stiffeners on bulkheads in deep tanks, and the stiffeners are to be bracketed at both ends.

16.3.1.5 Where single bottom is fitted in way of wing tanks, attention is to be given to a smooth transition of the inner bottom plating of the double bottom in way of center holds into single bottom wind tanks. The inner bottom plating is to be extended into the wing tank with a sufficient width and bracketed to the bulkhead or strength frame ring. The thickness $t$ (mm) of bracket is not to be less than $5+0.025L$, where the $L$ is the length of ship (to be taken not greater than 300m for calculation), and the thickness of bracket is to be given a smooth transition of inner bottom plating.

16.3.1.6 Where single bottom is fitted in way of wing tanks and if intermediate floors are fitted only in way of centre hold bottom between strength frame rings, attention is to be given to a smooth transition of the floors into wind tanks, and vertical brackets are to be fitted in corresponding positions within wing tanks. Such brackets are, in general, to extend transversely over a sufficient width and vertically to a sufficient height above the extension of inner bottom plating in wing tanks. The thickness of the brackets may be the same as that of plate floors. The thickness of brackets may be directly calculated for ore carriers with the length of 150m and above, but not less than the minimum thickness of solid floors required in 16.3.1.8.

16.3.1.7 Where the double bottom is interconnected with wing tanks or centre holds are used as storm ballast tanks, the scantlings of which are also to comply with the requirements in Section 13, Chapter 2 of this PART for deep tanks.

16.3.1.8 The minimum thickness of solid floors is not to be less than the value calculated by the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 2.5, 12\right) \qquad \text{mm}$$

where: $L$ – length of ship, in m, to be taken not greater than 300 m for calculation.

### 16.3.2 Single bottom

16.3.2.1 The section modulus $W$ of bottom longitudinals is not to be less than that obtained by the following formula:

$$W = 11.5sdl^2K \qquad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;
$d$ — draught, in m;
$l$ — span of longitudinal, in m;
$K$ — material factor.

16.3.2.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

16.3.2.3 Floors are to be spaced not more than 3.6 m apart. The section modulus $W$ and the net floor area $A$ of floors at the span point are not to be less than those obtained as follows, but not greater than those of corresponding centre hold floors:

$$W = 4.59\ SDl^2K \text{ cm}^3$$
$$A = 0.56\ SDlK \quad \text{cm}^2$$

where: $S$ — spacing of floors, in m;
$D$ — moulded depth, in m;
$l$ — span of floor, in m;
$K$ — material factor.

16.3.2.4 The spacing and scantlings of bottom girders are to be determined by direct calculation.

### 16.3.3 Deck framing

16.3.3.1 The deck framing is to comply with the relevant requirements of Section 8, Chapter 2 of this PART.

16.3.3.2 The buckling of deck structure between hatchways is to be checked.

### 16.3.4 Side framing

16.3.4.1 The ship's sides are normally longitudinally framed, and the side longitudinals within $0.1D$ from bottom and deck are to continuously pass through transverse bulkheads. The section modulus $W$ of side longitudinals is, in addition to satisfying relevant requirements of 2.7.5, Chapter 2 of this PART, not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2)l^2K \quad \text{cm}^3$$

where: $s$ — spacing of longitudinals, in m;

$h$ — vertical distance measured from the longitudinal under consideration to deck line at side amidships, in m, but not less than 2.5 m;

$l$ — span of longitudinal, in m;

$K$ — material factor.

16.3.4.2 Web frames are to be fitted in the plane of plate floors of longitudinally framed bottom.

16.3.4.3 The section modulus $W$ of web frames is not to be less than that obtained by the following formula:

$$W = CS(h + 1.2)l^2K \quad \text{cm}^3$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance measured from the mid-span of web frame to deck line at side, in m;

$l$ — span of web frame, in m;

$C$ — coefficient: $C$ = 11, without horizontal strut; $C$ = 3.2, with 1 horizontal strut; $C$ = 3, with 2 horizontal struts;

$K$ — material factor.

16.3.4.4 The net web area $A$ of web frames is not to be less than that obtained by the following formula:

$$A = C_1S(h + 1.2)lK \quad \text{cm}^2$$

where: $S$ — spacing of web frames, in m;

$h$ — vertical distance measured from the mid-span of web frame to deck line at side, in m;

$l$ — span of web frame, in m;

$C_1$ — coefficient: $C_1$ = 0.5 at section of span points and 0.25 at other sections, with 1 horizontal strut; $C_1$ = 0.66 at section of span points and 0.33 at other sections, with 2 horizontal struts;

$K$ — material factor.

16.3.4.5 The dimensions of web frames may be directly calculated for ore carriers with the length of 150 m and above.

### 16.3.5 Strength frame rings in wing tanks

16.3.5.1 The strength frame ring in wing tanks is composed of web beams, web frames, plate floors, vertical girders on the longitudinal bulkhead and cross ties.

16.3.5.2 The spacing $S$ of strength frame rings is not to be more than that obtained by the following formula:

$$S = 0.006L + 3.2 \quad \text{m, but not greater than 5.6 m}$$

where: $L$ — length of ship, in m.

16.3.5.3 Cross ties are to comply with the relevant requirements of Section 8, Chapter 5 of this PART. The dimensions of cross ties may be directly calculated for ore carriers with the length of 150m and above.

16.3.5.4 The cross ties are to be subject to integral buckling check as beams.

16.3.5.5 The minimum thickness of webs of strength frame rings in wing tanks is not to be less than the value calculated by the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 2.5, 12\right) \quad \text{mm}$$

where: $L$ – length of ship, in m, to be taken not greater than 300m for calculation.

### 16.3.6 Cargo hold boundary

16.3.6.1 Cargo hold boundary means longitudinal bulkhead, corrugated transverse bulkhead as well as upper and lower stool (if any), plane transverse bulkhead, upper deck and hatch coaming in the cargo hold (except for inner bottom) which are in contact with cargo.

16.3.6.2 Thickness $t$ of cargo hold boundary plate is not to be less than the value obtained from the following formula:

$$t = 4.65C_1s\sqrt{\frac{K_C HK}{\gamma}} \quad \text{mm}$$

where: $s$ — length of shorter side of plate panel, in m;

$\gamma$ — loading rate, in $\text{m}^3/\text{t}$, not to be more than 0.833;

$H$ — vertical distance measured from lower edge of panel to deck in way of midship side, in m;

$C_1 = 1.2 - \frac{s}{2l}$, where $l$ is length of longer side of plate panel, $C_1$ is to be taken as 1 for $C_1 > 1$;

$K_C$ — cargo pressure coefficient, to be taken as:

$Kc = \cos^2 \alpha + (1 - \sin \psi) \sin^2 \alpha$ for transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool and hatch coaming;

$Kc = 0$ for upper deck and inclined upper stool;

where: $\alpha$ — included angle between considered plate and horizontal plane, in degree;

$\Psi$ — angle of repose assumed for cargo in bulk, in degree, to be taken as 35° for carriage of ore;

$K$ — material factor.

16.3.6.3 Section modulus $W$ of cargo hold boundary stiffener is not to be less than the value obtained from the following formula:

$$W = \frac{8.5}{\gamma} K_C H s l^2 K \quad \text{cm}^3$$

where: $\gamma$ and $K_C$ — the same as those in 16.3.6.2;

$l$ — span of stiffener, in m;

$s$ — spacing of stiffeners, in m;

$H$ — vertical distance measured from the midpoint of span of stiffener to deck in way of midship side, in m;

$K$ — material factor.

### 16.3.7 Web stiffeners of non-watertight primary members within cargo hold area

16.3.7.1 Where the dimensions of web stiffeners of non-watertight primary members within cargo hold area are calculated, the thickness deduction listed in 16.3.7.1 is to be reduced.

Thickness Deduction Table 16.3.7.1

| Location | Thickness deduction (mm) |
|---|---|
| Both sides within ballast tanks | 2.0 |
| Elsewhere | 1.0 |

16.3.7.2 Net thickness of web stiffeners is to satisfy the following criteria:

(1) Minimum net thickness of stiffener web plate

The net thickness of stiffener web plate is not to be less than 3.0+0.015$L$, where $L$ is ship length ($L$ need not be taken greater than 300 m during calculation).

(2) Stiffener web plate

$$t_w \geq \frac{h_w}{C_w} \sqrt{\frac{R_{eH}}{235}}$$

(3) Flange

$$t_f \geq \frac{b_{f-out}}{C_f} \sqrt{\frac{R_{eH}}{235}}$$

where: $C_w$, $C_f$ — slenderness coefficient given in Table 16.3.7.2;

$b_{f\text{-}out}$ — maximum distance, in mm, from mid thickness of the web to the flange-edge, as shown in Figure 16.3.7.2;

$h_w$ — depth of stiffener web, in mm, as shown in Figure 16.3.7.2;

$t_f$ — net flange thickness, in mm;

$t_w$ — net thickness of plate, in mm;

$R_{eH}$ — Specified minimum yield stress of the plate material, in N/mm$^2$.

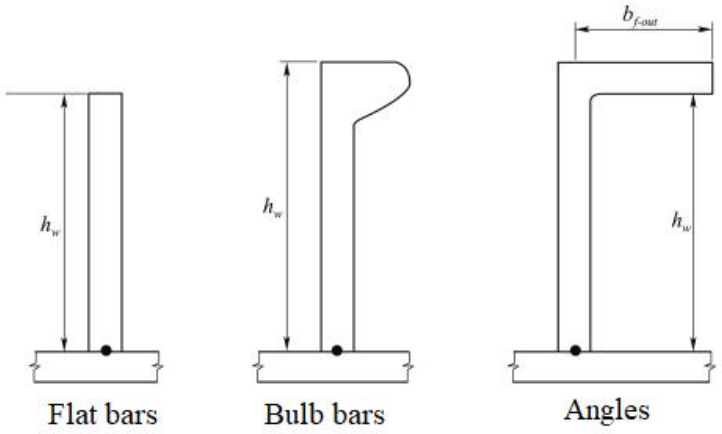



Figure 16.3.7.2 Stiffener Scantling Parameters

Slenderness Coefficients Table 16.3.7.2

| Type of stiffener | $C_w$ | $C_f$ |
|---|---|---|
| Angle bars | 75 | 12 |
| Bulb bars | 45 | - |
| Flat bars | 22 | - |

16.3.7.3 The total flange breadth $b_f$, in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geqslant 0.25 h_w$$

where: $h_w$ — as defined in 16.3.7.2;

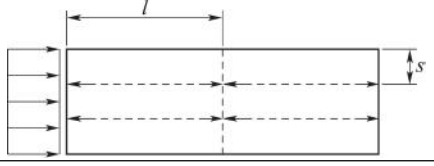
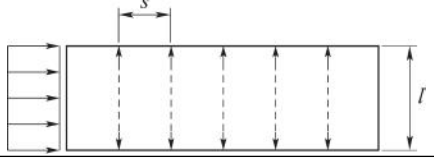
16.3.7.4 Bending stiffness of web stiffeners

The net moment of inertia, in cm$^4$, of web stiffener, $I_{st}$, fitted on non-watertight primary members within cargo hold area onboard ore carriers, with effective attached plate, $s_{eff}$, is not to be less than the minimum moment of inertia defined in Table 16.3.7.4, the breadth of effective attached plate $s_{eff}$, is to be calculated by the following formula:

$$s_{eff} = 0.8s \quad \text{mm}$$

where: $s$ — breadth of web plate panel, in mm, to be taken as the spacing of web stiffeners.

Stiffness Criteria for Web Stiffeners Table 16.3.7.4

| Stiffener arrangement | | Minimum moment of inertia of web stiffeners, in cm$^4$ |
|---|---|---|
| A | Web stiffeners fitted along the primary member span   | $I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$ |
| B | Web stiffeners fitted normal to the primary member span   | $I_{st} \geq 1.14 l s^2 t_w \left( 2.5 \frac{1000l}{s} - 2 \frac{s}{1000l} \right) \frac{R_{eH}}{235} \cdot 10^{-5}$ |

where: $C$ — slenderness coefficient to be taken as:

$C = 1.43$ for longitudinal stiffeners including sniped stiffeners;

$C = 0.72$ for other stiffeners.

$l$ — length of web stiffener, in m.

(1) For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local supporting members.

(2) For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary member as shown for stiffener arrangement B.

| Stiffener arrangement | Minimum moment of inertia of web stiffeners, in $cm^4$ |
|---|---|
| $A_{eff}$ — net section area of web stiffeners, including attached plate with effective width assumed to be 80% of stiffener spacing $s$, in $cm^2$.<br>$t_w$ — net web thickness of the primary member, in mm.<br>$R_{eH}$ — specified minimum yield stress of the material of the web plate of the primary member, in $N/mm^2$. | |

# Section 4 BULKHEADS

### 16.4.1 Transverse watertight bulkheads

16.4.1.1 Transverse watertight bulkheads are to be fitted with plate floors at bottom.

16.4.1.2 The scantlings of upper and lower stools of transverse watertight bulkheads are, if fitted, to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

16.4.1.3 The transverse bulkheads forming the boundary of ballast holds are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.

16.4.1.4 The thickness of the lowest strake of transverse watertight bulkheads is to be not less than that of inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered upwards.

### 16.4.2 Longitudinal watertight bulkheads

16.4.2.1 Longitudinal watertight bulkheads are to be plane, and framed longitudinally in general.

16.4.2.2 The longitudinal bulkheads are to be fitted with continuous bottom girders.

16.4.2.3 The scantlings of the longitudinal bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

16.4.2.4 The thickness of the longitudinal bulkhead plating in way of the knuckle is to be appropriately increased and the knuckle may be strengthened by horizontal girders to improve resistance to transverse compressive buckling stresses. The scantlings of the horizontal girders are to be determined by direct calculation.

16.4.2.5 Primary members are to be fitted at any vertical knuckle of longitudinal bulkhead. Distance between knuckle and primary members is not to be greater than 70 mm. Where the knuckle is not vertical, it is to be strengthened appropriately with normal stiffeners in the same line with the knuckle or other equivalent measures are to be taken.

16.4.2.6 Bulkhead plating

(1) The thickness $t$ of bulkhead plating is not to be less than that obtained by the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$h$ — vertical distance, in m, measured from lower edge of strake to tank top on the centreline, but not less than $0.4D$;
$K$ — material factor.

(2) The thickness $t$ of bulkhead plating within $0.1D$ from deck is not to be less than that obtained by the following formula:

$$t = 4.2s\sqrt{DK} + 2.5 \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$D$ — moulded depth, in m;
$K$ — material factor.

(3) The thickness $t$ of bulkhead plating is to additionally comply with the following:

$$t \geq as/27D \quad \text{mm}$$

where: $s$ — spacing of stiffeners, in m;
$a$ — vertical distance, in m, measured from $D/2$ to the centre of panel;
$D$ — moulded depth, in m.

(4) The thickness of the lowest strake of the longitudinal bulkheads is not to be less than that of adjacent inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered to the thickness of longitudinal bulkhead plating.

(5) The thickness of longitudinal bulkhead plating within $0.1D$ from deck need not exceed the sheer strake thickness with the same spacing of frames.

16.4.2.7 Vertical webs

(1) The vertical webs on longitudinal bulkheads are to be fitted within wing tanks, and the dimensions of the vertical webs are to be calculated according to 16.3.4.3 of this Chapter, and direct strength calculation may be carried out for ore carriers with the length of 150m and above.

(2) The brackets at both ends of the vertical web are to comply with the relevant requirements of 1.2.7 of Chapter 1 of this PART.

(3) Buckling-restrained stiffeners are generally to be fitted onthe vertical web plating.

16.4.2.8 Horizontal stiffeners

(1) The section modulus $W$ of horizontal stiffeners is not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2)l^2K \qquad \text{cm}^3$$

where: $s$ — spacing of horizontal stiffeners, in m;

$h$ — vertical distance, in m, measured from horizontal stiffener to tank top on the centreline, but not less than 2.5 m;

$l$ — span of horizontal stiffener, in m;

$K$ — material factor.

(2) Horizontal stiffeners are to continuously pass through transverse bulkheads within $0.1D$ from deck and inner bottom.

### 16.4.3 Wash bulkheads

16.4.3.1 Where necessary, plane perforated wash bulkheads are to be fitted in wing tanks.

16.4.3.2 Wash bulkheads are to comply with the relevant requirements of Section 11, Chapter 5 of this PART.

## Section 5 EASY LOADING REQUIREMENTS

### 16.5.1 General requirements

16.5.1.1 This Section applies to ore carriers having a single hold being capable of loading 100% (easy loading) capacity in one step for all cargo holds.

16.5.1.2 Average loading rate during easy loading is not to be more than the provisions in Table 16.5.1.2. Higher average loading rate is to be specially considered.

**Average loading rate** **Table 16.5.1.2**

| Deadweight tonnage (t) | Average loading rate (t/h) |
|---|---|
| 220,000 ~ 250,000 | 14,000 |
| > 250,000 | 16,000 |

### 16.5.2 Hull structure strength

16.5.2.1 In the whole process of easy loading, actual still water bending moment and still water shearing force of hull girder are not to exceed permissible still water bending moment and permissible still water shearing force in harbor condition.

16.5.2.2 In the whole process of easy loading, it is to be ensured that double bottom and transverse bulkhead have sufficient local strength, and direct calculation of structural strength is to be carried out in accordance with CCS Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers.

### 16.5.3 Equipment provision and requirements

16.5.3.1 If ballast adjustment is required to control that actual still water bending moment and still water shearing force of hull girder do not exceed permissible still water bending moment and still water shearing force in harbor condition, requirements of 16.5.3.2 and 16.5.3.3 are to be complied with.

16.5.3.2 The ballast system is to be able to match the requirements of mean loading rate in 16.5.1.2, including ballast tank arrangement, capacity of ballast pump and arrangement of ballast piping system.

16.5.3.3 The ship is to be provided with tank (e.g. ballast tank, fuel oil tank, etc.) remote control sounder and ship draught reading system, which are synchronous with loading instrument on board. It is not necessary to consider fuel oil tanks without level change during loading.

### 16.5.4 Requirements of easy loading manual

16.5.4.1 Approved easy loading manual is to be provided on board or may be included in other approved

loading manual.

16.5.4.2 Easy loading sequence is to include operation sequence of each step of loading from the beginning to the end as well as synchronous ballast adjustment, so as to ensure that the requirements of 16.5.2.1 are complied with during loading (including each cargo hold from empty load to full load).

16.5.4.3 Easy loading manual is at least to include following:

(1) loading capacity in each hold for each step;

(2) ballast water adjustment in each ballast tank for each step;

(3) maximum still water bending moment and shearing force at the end of each step;

(4) ship’s draught and trim at the end of each step.

# CHAPTER 17 LAUNCHING WORK BARGES

## Section 1 GENERAL PROVISIONS

### 17.1.1 General requirements

17.1.1.1 This Chapter applies to non-self-propelled work barges dedicated to launching ships or offshore installations under construction, or moving from water to shore, within shipyard and/or port waters, and short-distance movement within the above-mentioned waters.

17.1.1.2 For those not covered in this Chapter, the relevant requirements of Chapter 2 of this PART and of CCS Rules for Classification of Floating Docks are to be complied with.

### 17.1.2 Plans and documents

17.1.2.1 The following plans and documents are to be submitted for information in addition to those as specified in Section 1, Chapter 2 of this PART:

(1) Hydrostatic curves, lifting and submersing curves;

(2) Operating manual.

### 17.1.3 Definitions

17.1.3.1 Launching work barge means a dedicated barge used for launching operation, having larger open pontoon deck, bow and/or stern, and higher superstructure or deck house on both sides. The superstructure on both sides may be arranged discontinuously along the longitudinal direction, and some of the superstructure or deck house may be removed where necessary. Special crane rails and trolleys are to be provided on the pontoon deck. Where the objects intended for moving is being moved from shore to water or from water to shore, the pontoon deck is to be maintained on the same level as the shore land, then the object is to be moved by the trolley. The in-water loading/unloading operation may be carried out by the ship's lifting and submerging. Cranes are not provided onboard. Figure 17.1.3.1 shows a diagram of typical launching work barge.

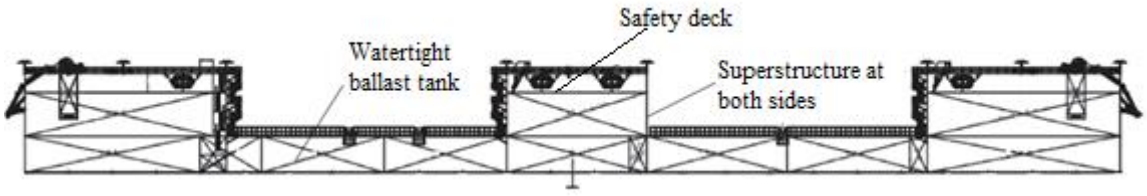
17.1.3.2 Semi-submerged condition means any condition in which the pontoon deck is submerged and reserve buoyancy is provided by the superstructure or deckhouse or pontoon only.

17.1.3.3 Pontoon deck means an open weather deck which is used for the carriage of objects intended for moving and is submerged during loading/unloading operation, also referred to as lifting cargo deck.

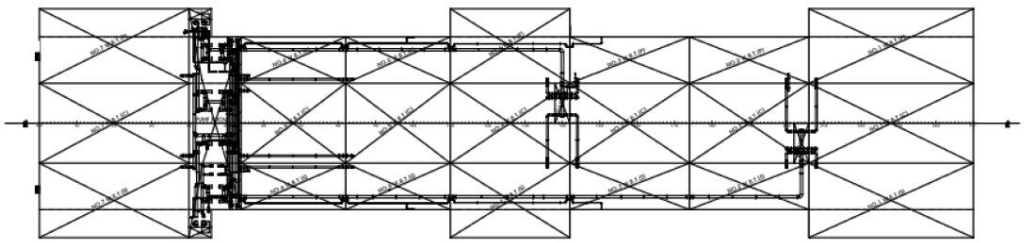
17.1.3.4 Maximum submerged depth means a maximum draft to which the vessel is allowed to be submerged in semi-submerged operating conditions.

17.1.3.5 Length of pontoon $L_D$ (m) means a distance from the aft end of the aftermost pontoon to the fore end of the forward pontoon of a launching work barge, but is exclusive of non-integral end platforms or swing bridges.

17.1.3.6 Safety deck means a deck extending over superstructure or deck house on both sides, and located below the top deck and above the ballast tank, which is watertight at the positions of ballast deck.




Longitudinal section at port



Plane of ballast tank

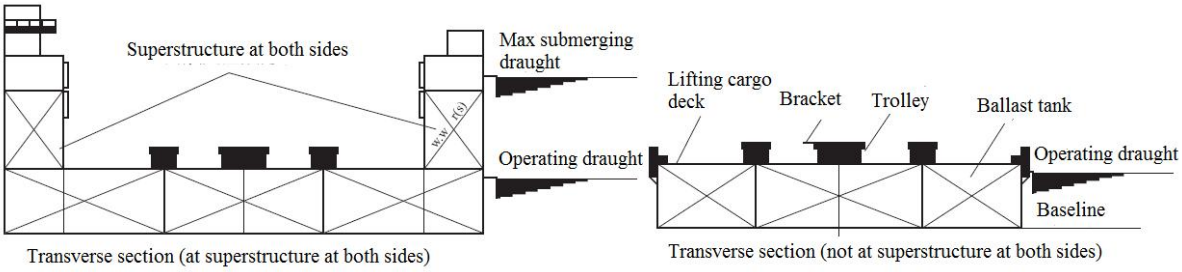



**Figure 17.1.3.1 Diagram of a Certain Typical Launching Work Barge**

# Section 2 LONGITUDINAL STRENGTH

### 17.2.1 General requirements

17.2.1.1 Unless otherwise specified in this Section, the longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART.

17.2.1.2 The longitudinal strength is to include the terminal operating conditions and harbor operating conditions, if any.

17.2.1.3 Structural members of the hull girder based on section modulus are to be maintained longitudinally continuous within $0.4L_D$ amidships, excluding the crane rails.

### 17.2.2 Loads

The loads of longitudinal strength are specified as follows:

(1) The buoyancy is to be assumed to distribute homogeneously along the ship's length.

(2) The weight of objects and distribution are to be assumed according to the following design conditions:

① In the case of the objects intended for moving being placed onboard: it is assumed that the total weight of objects based on designed lifting capacity is distributed to trolleys of the launching work barge according to the actual condition, then transferred to the pontoon deck below through trolleys. In calculation, the total capacity of trolleys is to be taken as the total weight of objects intended for moving, otherwise, disequilibrium of the buoyancy and weight will be caused on the general force system. In addition, the maximum load capacity of trolleys is not to be less than the distributed load on a single trolley.

② In the case of the objects being moved onboard: it is assumed that the weight distribution of object intended for moving is as the same as that in ①, and only partial length of the object is moved inboard, the bending strength and shearing strength in way of the weak section are to be checked according to the actual ballast water condition. In this case, the draught of work barge is to be based on the sea surface elevation due to tide variation, the partial weight of the object moved inboard, the weight of work barge and the hydrostatic equilibrium of buoyancy.

(3) The still water bending moment and shear force under all actual operating conditions (which are to include the typical ones of most unfavorable conditions for objects to be launched or moved to shore, and in the operation of lifting/submerging objects, etc.) are to be taken into account.

### 17.2.3 Longitudinal strength check

17.2.3.1 The longitudinal strength is to be checked in accordance with the requirements of Section 2, Chapter 2 of this PART, and complying with the following requirements:

(1) For terminal operating conditions, the allowable bending stress is to be taken $137/K$, in N/mm$^2$; the shear stress is to be taken $95/K$, in N/mm$^2$ ($K$ being the material factor, but not less than 0.72).

(2) For harbor operating conditions, the allowable bending stress is to be taken $175/K$, in N/mm$^2$; the shear stress is to be taken $110/K$, in N/mm$^2$ ($K$ being the material factor, but not less than 0.72).

(3) The minimum section modulus $W_0$ amidships is not required.

(4) For terminal operating conditions of launching work barges, the wave loads are not to be included.

(5) For harbor operating conditions of launched work barges, the wave loads are to be taken 50% of that as required in Section 2, Chapter 2 of this PART.

# Section 3 TRANSVERSE STRENGTH

### 17.3.1 General requirements

17.3.1.1 The transverse strength is to be calculated for typical transverse structures throughout the length of ship in accordance with the requirements of this Section. In addition to the yield strength calculation, the plate panels and transverses subject to transverse bending moment and shear stresses are to be checked for buckling according to the requirements of 2.2.7 in Section 2, Chapter 2 of this PART.
17.3.1.2 The transverse strength of fore and aft ends of the pontoon is not to be lower than that as required for the mid-portion of the pontoon.

**17.3.2 Loads**
17.3.2.1 The primary transverse strength members of launching work barges, throughout its length $L_D$, is to be suitable for the sum of the following load components (normally, the weight of the rail, trolley and its facilities, as well as the hydrostatic pressure effect on horizontal action may be neglected):
(1) self-weight of the launching work barge (including the weight of superstructure or deck house on both sides and pontoon);
(2) weight of object intended for moving, see 17.2.2 of this Section;
(3) external hydrostatic pressure due to a given draught. The most severe condition normally occurs when the draught is equal to the depth to the top of the trolley bracket (i.e. the bottom of the object intended for moving is just lifted above the water surface);
(4) internal hydrostatic pressure due to the level of evenly distributed ballast associated with the draught as in (3) above;
(5) hydrostatic pressure of the outside of pontoon's bottom;
(6) reaction forces (if any) on superstructure or deck house longitudinal bulkheads on both sides required for achieving equilibrium of the buoyancy and weight on the section under consideration. Such reaction forces applied on internal and external longitudinal bulkheads on both sides of superstructure or deck house may be assumed as equal.

**17.3.3 Calculation model**
17.3.3.1 The transverse bending strength and shear strength of some typical longitudinal sections taken over the transverse length (where symmetrical, only half the breadth may be taken) of the pontoon are to be checked. The spacing of transverse bulkheads is to be taken as the longitudinal length of the section calculated, and the weak points of transverse strength are to be included in the check point of the section.
17.3.3.2 When lifting at maximum capacity with a launching work barge length less than that of the pontoon, the sections clear of the ship will experience transverse hogging due to the combination of loads in 17.3.2.1(1), (3), (4), (5) and (6). Hence, such condition is to be checked as appropriate for the sections concerned. The most severe condition will usually occur when the ballast depth is at a minimum (i.e. residual water only).

**17.3.4 Transverse strength check**
17.3.4.1 The permissible stress of transverse primary members are to be as follows:

permissible normal stress $[\sigma] = 170/K$ N/mm$^2$;

permissible shear stress $[\tau] = 95/K$ N/mm$^2$;

permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 180/K$ N/mm$^2$.

17.3.4.2 Special care is to be taken to the maintenance of transverse strength standard (not to be lower than that of 17.3.4.1) in end sections of launching work barges with swim ends where the pontoon depth is reduced.

# Section 4 LOCAL STRENGTH

**17.4.1 General requirements**
17.4.1.1 Scantlings of the hull structural members are not to be less than that as specified in this Section, and to be adequate to meet the requirements for longitudinal strength, transverse strength and direct calculation.
17.4.1.2 Primary structural members, such as longitudinals, beams and ordinary frames of pontoons are to be maintained continuous, and transitional brackets are to be fitted where it is interrupted.
**17.4.2 Tank boundary plating**
17.4.2.1 The thickness of boundary plating of ballast water tanks, oil tanks, fresh water tanks, bilge tanks, empty tanks, etc., is not to be less than that obtained from the following formula:

$$t = t_0 + 2.5 \quad \text{mm}$$

where: $t_0 = 3.95s\sqrt{\rho hK}$ mm, when $l/s$ is less than 4, the thickness obtained from the above formula is to be multiplied by the factor: $1.1 - \frac{s}{2.5l}$;

$s$ — spacing of stiffeners, in m;
$K$ — material factor;
$h$ — calculated head, in m, taken as in Table 17.4.2.1;
$l$ — span of stiffener, in m.

**Table 17.4.2.1**

| Location of members | Calculated head $h$ (m) | Remarks |
|---|---|---|
| 1. Boundary plating subjected to external hydrostatic pressure and internal hydrostatic pressure on both sides, such as longitudinal bulkhead plating of watertight ballast tank of superstructure, shell plating of pontoon, etc. | The maximum differential head in the position obtained from the lifting and submersing curve | |
| 2. Boundary of ballast water tank | The maximum differential head between two sides, not less than 3.5 m | |
| 3. In way of air cushion space, such as the safety deck, longitudinal bulkhead plating, inner bulkhead plating of watertight ballast tank of superstructure | Internal head on the cushion side: differential head in the position under maximum submerged depth from the lifting and submersing curve. The head is taken as the differential between internal and external pressures, not less than 3.5 m | Also in compliance with the requirements in 1 and 2 above |
| 4. Watertight boundary of empty tank | The vertical distance from the considered point to the deepest submersing water level, not less than 3.5 m | Also in compliance with the requirements in 3 above |
| 5. Normal oil tanks, fresh water tanks and bilge tanks other than that mentioned above | The vertical distance from the considered point to the top of tank, or half of the vertical distance from the considered point to the top of overflow pipe, whichever is the greater | |

17.4.2.2 The minimum thickness of boundary plating of tanks and non-watertight bulkheads is to be 7.5 mm.

### 17.4.3 Stiffeners on boundary plating

17.4.3.1 For structural members subjected to lateral pressure on tank boundary plating as defined in 17.4.2.1 of this Section, such as bulkhead stiffeners, longitudinals, beams and ordinary frames, etc., the minimum section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 7shl^2K \quad \text{cm}^3$$

where: $s$ —spacing of stiffeners, in m;
$K$— material factor;
$l$ — span of stiffener, in m, between effective supporting members;
$h$ — calculated head, in m, see 17.4.2.1, measured from the mid span.

### 17.4.4 Top deck plating of superstructure on both sides

17.4.4.1 The plating thickness $t$ of top deck of superstructure on both sides within the following two areas is not to be less than the value calculated from the following formulae, and not less than 6.5 mm:

$t = 10s\sqrt{K}$ mm, within $0.4L_D$ amidships
$t = (7.8s + 2.2)\sqrt{K}$ mm, $0.1L_D$ from each end of the pontoon

where: $s$ — spacing of longitudinals, in m;
$K$ — material factor.

17.4.4.2 The thickness of top deck plating within 0.4 $L_D$ amidships is to be greater than that of the end.

### 17.4.5 Top deck longitudinals and beams of superstructure or deck house on both sides

17.4.5.1 The section modulus $W$ of top deck longitudinals and beams of superstructure or deck house on both sides is not to be less than the value calculated from the following formula:

$$W = Csl^2 \quad \text{cm}^3$$

where: $C$ —14.5 for longitudinal beam within 0.4 $L_D$ amidships, 5.4 for transverse beam and longitudinal beam at the fore and aft ends;

$s$ — spacing of longitudinal or transverse beams, in m;
$l$ — span of longitudinal or transverse beams, in m.

**17.4.6 Safety deck plating**

17.4.6.1 The thickness $t$ of the safety deck plating is not to be less than that obtained from the following formula:

$$t = t_0 + 2.5$$

when $l/s < 4$, $t_0$ is to be multiplied by the factor: $1.1 - \frac{s}{2.5l}$

where: $t_0 = 3.4s\sqrt{hK}$ mm;

$K$ — material factor;
$s$ — spacing of stiffeners, in m;
$l$ — span of stiffener, in m;
$h$ — height from top of safety deck beam to top of upper deck beam at side, in m.

17.4.6.2 In addition to 17.4.6.1, special consideration is to be given to the thickness of safety deck where the deck is subjected to the air cushion and goods/equipment separately.

17.4.6.3 The minimum thickness of the safety deck plating is to be 7.5 mm.

**17.4.7 Longitudinals and beams of safety deck**

17.4.7.1 The section modulus $W$ of each safety deck longitudinals or beams is to be obtained from the following formula:

$$W = 4.5Kshl^2 \quad \text{cm}^3$$

where: $K$ — material factor;
$s$ — spacing of stiffeners, in m;
$l$ — span of stiffener, in m;
$h$ — height from top of safety deck beam to top of upper deck beam at side, in m.

17.4.7.2 In addition to 17.4.7.1, special consideration is to be given to the check of scantlings where the deck is subjected to the air cushion and goods/equipment separately.

**17.4.8 Webs, transverses, floors and girders**

17.4.8.1 For primary supporting members such as webs, transverses, floors and girders, the minimum section modulus $W$ is not to be less than that obtained from the following formula:

$$W = 7bhl^2K \quad \text{cm}^3$$

where: $b$ — supporting width, in m, spacing of primary supporting members;
$K$— material factor;
$l$ — calculated span, in m;
$h$ — calculated head, in m, see 17.4.3.1, measured from the mid span.

**17.4.9 Cross ties**

17.4.9.1 The sectional area, web and face plate of cross ties fitted in deck house on both sides and pontoon, are to be in accordance with the requirements of 17.4.9.4 and 17.4.9.5 of this Section.

17.4.9.2 The load $P$ supported by the horizontal cross ties is not to be less than that obtained from the following formula:

$$P = p \quad \text{kN}$$

where: $p = 9.8shl_1$;

where: $h$ — maximum differential head, in m;
$s$ — spacing of cross ties, in m;
$l_1$ — vertical midspan-to-midspan distance between two members immediately over and under the horizontal cross ties, in m, see Figure 17.4.9.3.

17.4.9.3 The load $P$ supported by the diagonal cross ties is not to be less than that obtained from the following formula:

(1) For diagonal cross tie 1 (see Figure 17.4.9.3):

$$P = \frac{p\sin\beta}{\sin(\alpha+\beta)} \quad \text{kN}$$

where: $p$ — see 17.4.9.2, and $h$ to be measured from the lower edge of diagonal cross ties to the water level at maximum differential head;
$\alpha, \beta$ — angles between diagonally arranged cross ties and horizontal plane, (º), see Figure 17.4.9.3.

(2) For diagonal cross tie 2 (see Figure 17.4.9.3):

$$P = \frac{p \sin \alpha}{\sin(\alpha + \beta)} \qquad \text{kN}$$

where: $P$, $\alpha$ and $\beta$ — same as defined in (1).

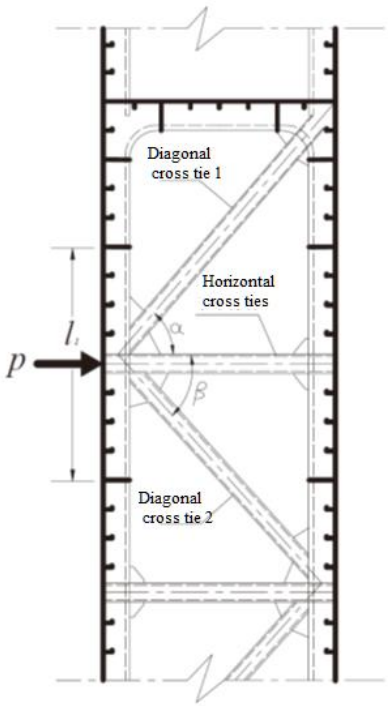



**Figure 17.4.9.3 Vertical midspan-to-midspan Distance $l_1$ between Two Members immediately over and under the Horizontal Cross Ties**

17.4.9.4 The cross-section area $A$ of cross ties is to comply with the requirements of 2.10.2, Section 10, Chapter 2 of this PART.

17.4.9.5 The built or rolled-section cross ties are to comply with the requirements of 2.10.3.2, Section 10, Chapter 2 of this PART.

### 17.4.10 Local strength of pontoon supporting structure below the trolley rail

17.4.10.1 The local strength of pontoon supporting structure below the trolley rail may be calculated and analysed as specified in 17.2.2 of this Section, based on the loads subjected to the supporting structure throughout the length of pontoon. The strength criteria are given in 17.3.4.1 of this Section. Check of such local strength may be included in the direct calculation of global strength.

### 17.4.11 Platforms extending from ends of pontoon

17.4.11.1 The load supported by the platform structures is generally to be assumed as 5.75 kN/m$^2$, the permissible stress $[\sigma]$ to be $60/K$, N/mm$^2$ and the permissible shear stress $[\tau]$ to be $35/K$, N/mm$^2$. Where a large load is to be expected or required, special consideration is to be given.

### 17.4.12 Swing bridges at ends of pontoon

17.4.12.1 The load supported by the bridge structures of launching work barge is generally to be assumed as 3.59 kN/m$^2$, the permissible stress $[\sigma]$ to be $60/K$, N/mm$^2$ and the permissible shear stress $[\tau]$ to be $35/K$, N/mm$^2$. Where a large load is to be expected or required, special consideration is to be given.

## Section 5 DIRECT STRENGTH CALCULATION

### 17.5.1 General requirements

17.5.1.1 Direct calculation of global strength is to be carried out for launching work barges as required in Appendix 1 of this Chapter, and to be submitted for approval.

# Appendix 1 DIRECT STRENGTH CALCULATION OF LAUNCHING WORK BARGES

## 1 General Provisions

### 1.1 Application

1.1.1 This Appendix applies to the direct strength calculation of launching work barges required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 9, Chapter 1 of this PART are to be complied with.

## 2 Design Loads

### 2.1 General requirements

2.1.1 The design loads are at least to include the following:

(1) self-weight of launching work barge;

(2) the weight of object intended for moving assumed in 17.2.2 of this Chapter only to be supported by pontoon;

(3) hydrostatic pressure of the outside of pontoon's bottom and external hydrostatic pressure;

(4) hydrostatic pressure on the immersed pontoon deck;

(5) hydrostatic pressure of the ballast tank.

## 3 Calculation Conditions

### 3.1 General requirements

3.1.1 The calculation conditions are at least to include the following, and to comply with the requirements of 17.2.2 of this Chapter and the characteristics of the ship:

(1) condition 1: the operating condition;

(2) condition 2: the condition that the top of the trolley bracket are just submerged by the water when the launching work barge is lifting at maximum capacity;

(3) condition 3: the severe condition likely to occur while distributing ballast water when the floating dock sinks or rises.

3.1.2 The equilibrium of total buoyancy and weight of model is to be maintained as far as possible, see 1.5.7.6 of Section 5, Chapter 1 of this PART.

3.1.3 In applying the load of the object intended for moving, the coordinate of the maximum value of the weight curve is to be assumed to be at the center of the global ship model.

## 4 Structural Modeling

### 4.1 General requirements

4.1.1 The extent of global ship model is as follows:

(1) for longitudinal extent (in $x$-direction): total length of the ship;

(2) for transverse extent (in $y$-direction): total breadth of the ship;

(3) for vertical extent (in $z$-direction): from baseline to the top deck.

4.1.2 The relevant requirements for model element and mesh scantling are given in Section 5, Chapter 1 of this PART.

4.1.3 The boundary conditions are to restrict the rigid displacement for the global ship model, in general, the boundary is to be placed at fore and aft ends or web frame section of amidships, see Figure 4.1.3.

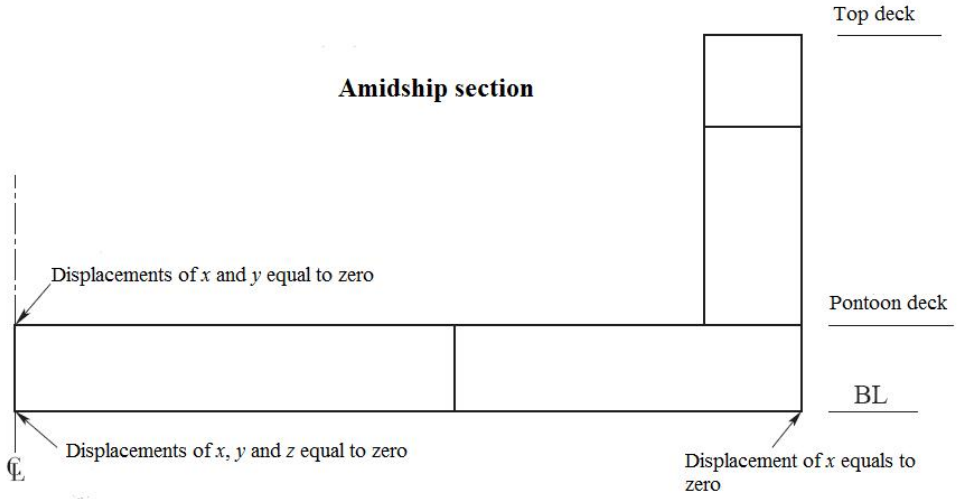



**Figure 4.1.3 Boundary Conditions**

## 5 Yielding Strength Assessment

### 5.1 Permissible stress

5.1.1 The permissible stress is given in Table 5.1.1.

**Permissible Stress** **Table 5.1.1**

| Structural component | Equivalent stress or axial stress (N/mm$^2$) | Shear stress (N/mm$^2$) |
|---|---|---|
| Plate element | $[\sigma_e]$ =185/$K$ | $[\tau]$ =100/ $K$ |
| Trusses in transverse sections | $[\sigma]$=141/ $K$ | – |

Note: $K$— material factor.

## 6 Buckling Strength Assessment

### 6.1 General requirements

6.1.1 The requirements for buckling strength assessment are given in Appendix 1, Chapter 5 of this PART.

# CHAPTER 18 TWIN-HULL CRAFT

## Section 1 GENERAL PROVISIONS

### 18.1.1 General requirements

18.1.1.1 This Chapter applies to twin-hull craft of which the main body is composed of the two demi-hulls connected by cross-deck.

18.1.1.2 For those not covered in this Chapter, the relevant requirements of Chapter 2 of this PART are to be complied with.

### 18.1.2 Definitions

18.1.2.1 Length $L$ (m) means the length measured along summer load line from the leading edge of the foremost vertical strut to the trailing edge of the aftermost vertical strut, plus 50% of difference between the length of lower hull from forward to end and the overall length of the underwater watertight envelope of the rigid hull (excluding appendages at or below the design waterline).

18.1.2.2 Breadth $B$ (m) means the breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages at or below the design waterline.

18.1.2.3 Moulded depth $D$ (m) means the vertical distance measured at the middle of the length $L$ from the top of keel to the lower surface of freeboard deck along the outside of demi-hull.

18.1.2.4 Breadth $b$ (m) of demi-hull means the maximum horizontal distance measured at the middle of the length $L$ between the outside surfaces of internal and external sides of demi-hull.

18.1.2.5 Breadth $b_1$ (m) of cross-deck structure means the horizontal distance measured at the middle of the length $L$ between outside surfaces of internal sides of port and starboard sets of struts of wet deck.

18.1.2.6 Cross-deck structure means the deck and other accessory strength (boxlike) structure that spans the port and starboard sets of struts.

18.1.2.7 Wet deck means the lower plated surface of the cross structure.

18.1.2.8 Port and starboard sets of struts means the longitudinal mono-hull structures in way of both sides below the cross-deck structure, respectively.

## Section 2 STRUCTURAL STRENGTH

### 18.2.1 General requirements

18.2.1.1 For port or starboard set of strut of twin-hull craft, the applicable requirements for mono-hull craft of this PART may be complied with.

18.2.1.2 For cross-deck structure, the minimum scantling is to meet the requirements of the Rules for strength deck of mono-hull craft, and a suitable strengthening is to be provided for resistance to the slamming effect on wet deck of cross-deck structure by wave loads.

18.2.1.3 The overall strength (including longitudinal strength, transverse strength and torsional strength) of twin-hull craft with cross-deck structure is to be checked in accordance with the direct calculation of global strength of twin-hull craft as specified in Appendix 1 of this Chapter.

18.2.1.4 The shear strength of the longitudinal section of cross-deck structure is to be calculated and checked with the shear force as specified in 18.3.2.4 of this Chapter and the shear stress is to meet the requirements of the following formula ($K$ is the material factor):

$$\tau \leqslant 90/K \quad \text{N/mm}^2$$

## Section 3 TOTAL LOAD

### 18.3.1 General requirements

18.3.1.1 The total load of ship may be determined in accordance with 18.3.2 of this Section or direct calculation of load may be carried out in accordance with 18.3.1.2 and 18.3.1.3 of this Section (if applicable) for twin-hull passenger ship and public service ship with the following characteristics:

$$L \leqslant 60 \text{ m}$$

$$L/D \leqslant 15$$

$B/D \leqslant 3.5$

$b_1/B \leqslant 0.4$

18.3.1.2 The total load of twin-hull craft beyond the scope of 18.3.1.1 is to be determined by direct calculation. The direct calculation of wave loads is to be carried out in accordance with 2.2.9 of Section 2, Chapter 2 of this PART. If strip theory is adopted, the analysis is to consider the hydrodynamic interaction between twin hulls.

18.3.1.3 Where the wave loads are obtained directly from model testing, the related calculation principles/calculation procedure or test program (if applicable) is to be approved in advance.

18.3.2 Load under consideration

18.3.2.1 The longitudinal bending moment $M_{by}$ of the twin-hull craft is the superposition of still water bending moment $M_{bys}$ and wave bending moment $M_{byw}$. The wave bending moment $M_{byw}$ is to be taken as twice the wave bending moment of the demi-hull which is to be determined in accordance with 2.2.3 of Section 2, Chapter 2 of this PART. The still water bending moment $M_{bys}$ is to be determined in accordance with 2.2.2 of Section 2, Chapter 2 of this PART. The still water bending moment is to be taken as the maximum value within 0.4$L$ midship under various loading conditions and the wave bending moment is to be taken within 0.4$L$ midship.

18.3.2.2 The transverse bending moment $M_{bx}$ of the cross-deck of twin-hull craft may be obtained by the following formula:

$$M_{bx} = 9.81 C_1 C_2 C_3 \Delta \ (b + b_1) \qquad \text{kN} \cdot \text{m}$$

where: $C_1 = 0.150(\frac{b}{D})^2 - 0.778\frac{b}{D} + 0.866$

$C_2 = -2.386\frac{b_1}{B} + 1.937$

where:

$b$ — breadth of demi-hull, in m;

$b_1$— breadth of cross-deck, in m;

$D$ — moulded depth of craft, in m;

$B$ — breadth of craft, in m;

$C_3$ — service coefficient, 1.0 for open sea areas, 0.8 for offshore areas, 0.6 for coastal areas and 0.5 for sheltered areas;

$\Delta$ — displacement of twin-hull craft, in t.

18.3.2.3 The transverse torque $M_{ty}$ of the cross-deck of twin-hull craft may be obtained by the following formula:

$$M_{ty} = 1.226 C_3 \Delta L \qquad \text{kN} \cdot \text{m}$$

where: $C_3$ — service coefficient, 1.0 for open sea areas, 0.8 for offshore areas, 0.6 for coastal areas and 0.5 for sheltered areas;

$\Delta$ — displacement of twin-hull craft, in t;

$L$ — length of craft, in m.

18.3.2.4 The vertical shear force $Q_t$ of the cross-deck of twin-hull craft may be obtained by the following formula:

$$Q_t = 9.81 C_1 C_2 C_3 \Delta \qquad \text{kN}$$

where: $C_1 = 0.164(\frac{b}{D})^2 - 0.874\frac{b}{D} + 0.974$

$C_2 = -1.958\frac{b_1}{B} + 1.783$

where:

$b$ — breadth of demi-hull, in m;

$b_1$— breadth of cross-deck, in m;

$D$ — moulded depth of craft, in m;

$B$ — breadth of craft, in m;

$C_3$ — service coefficient, 1.0 for open sea areas, 0.8 for offshore areas, 0.6 for coastal areas and 0.5 for sheltered areas;

$\Delta$ — displacement of twin-hull craft, in t.

# Appendix 1 DIRECT STRENGTH CALCULATION OF twin-hull craft

## 1 General Provisions

### 1.1 General requirements

1.1.1 This Appendix applies to the direct strength calculation of twin-hull craft.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

## 2 Loads

### 2.1 General requirements

2.1.1 During direct calculation, the loads may be applied in the form of equivalent loads as specified in 2.2.1 to 2.2.3 or may be carried out by the equivalent design wave method as specified in 2.2.4.

2.1.2 Where the equivalent loads are applied, the longitudinal bending moment $M_{by}$, transverse bending moment $M_{bx}$, transverse torque $M_{ty}$ are to be calculated in accordance with Section 3 of this Chapter and the loads include still water loads and wave loads.

### 2.2 Application of loads

2.2.1 For longitudinal bending moment $M_{by}$ of twin-hull craft, equivalent force $q(x)$ vertically distributed along craft length or a series of equivalent concentrated forces may be applied on calculation model. The loads are to be applied on longitudinal primary members of demi-hull, such as craft side, longitudinal bulkheads, bottom centre girders or other girders. The force acting on the same cross section of one hull may be divided into portions symmetrical to the longitudinal centerline section at port and starboard sides and the loads applied on two demi-hulls are to be symmetrical to the longitudinal centerline section of twin-hull craft. Where a series of concentrated forces are applied, each concentrated force is to be equal to the product of the distributed force multiplied by the length of areas loaded by the concentrated forces. $q(x)$ is to be obtained by the following formula:

$$q(x) = q_0\left(\sin\frac{\pi x}{L} - 0.637\right) \qquad \text{kN/m}$$

where: $q_0 = \dfrac{46}{L^2}M_{by}$ kN/m

where: $M_{by}$ is to be calculated in accordance with 18.3.2.1 of this Chapter.

2.2.2 For transverse bending moment $M_{bx}$ of cross-deck, its equivalency may be achieved by applying the transverse split force on the series nodes along the inside of the bilge of demi-hull, as shown in Figure 2.2.2. The transverse split force $f_y$ is to be obtained by the following formula:

$$f_y = \frac{M_{bx}}{nz} \qquad \text{kN}$$

where: $M_{bx}$ — transverse bending moment of cross-deck, in kN·m, to be calculated in accordance with this Chapter;

$z$ — the vertical distance from the application point of transverse split force to neutral axis of the longitudinal centerline section of cross-deck, in m;

$n$ — total number of nodes on which the transverse split force is applied for one demi-hull.

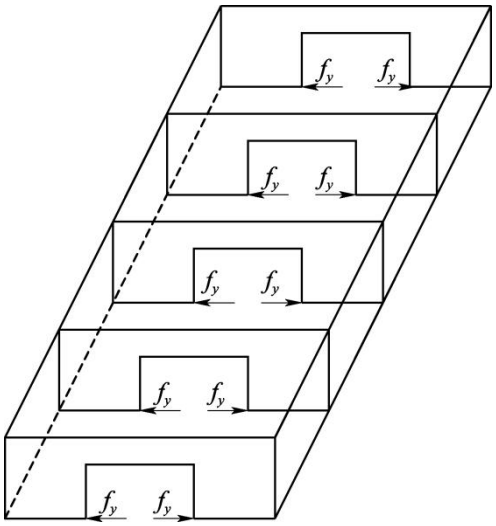



**Figure 2.2.2 The application of transverse bending moment through transverse split force**

2.2.3 For transverse torque $M_{ty}$ of twin-hull craft, its equivalency may achieved by applying the uniformly distributed vertical force which is asymmetrically distributed on longitudinal centerline section of the demi-hull. "Asymmetrically distributed" means uniformly distributed equivalent vertical force, namely to be asymmetrically to the longitudinal centerline section and transverse centerline section of twin-hull craft, as shown in Figure 2.2.3. The uniformly distributed equivalent vertical load $p_x$ is to be calculated by the following formula:

$$p_x = \frac{4M_{ty}}{L^2} \quad \text{kN/m}$$

where: $L$ — length of twin-hull craft, in m;

$M_{ty}$ — torque of cross-deck, in kN·m, to be calculated in accordance with this Chapter.

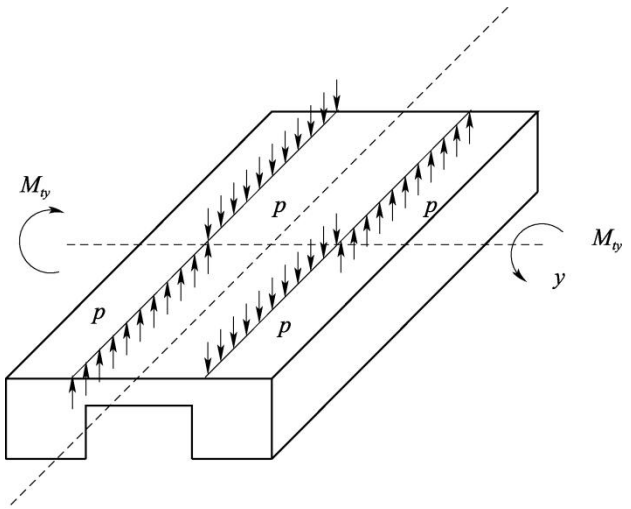



**Figure 2.2.3 The application of transverse torque through asymmetrically distributed vertical force**

2.2.4 The application of loads may also be carried out in accordance with 1.5.7 of Section 5, Chapter 1 of this PART. Relevant equivalent design wave is to be searched in accordance with the load combination conditions as specified in 3.1.1 of this Appendix.

## 3 Calculation Conditions

### 3.1 General requirements

3.1.1 The direct calculation of the structural strength of twin-hull craft is to be carried out in accordance

with the load combination conditions (1) to (6) below and supplementary calculation is to be carried out in accordance with the load combination conditions (7) to (12) below for ships over 50 m in length:
(1) $M_{bx}$ (inward);
(2) $M_{bx}$ (outward);
(3) 0.8 $M_{bx}$ (inward)＋0.6$M_{ty}$;
(4) 0.8 $M_{bx}$ (outward)＋0.6 $M_{ty}$;
(5) 0.6 $M_{bx}$ (inward)＋0.8 $M_{ty}$;
(6) 0.6 $M_{bx}$ (outward)＋0.8 $M_{ty}$;
(7) $M_{by}$ (hogging);
(8) $M_{by}$ (sagging);
(9) 0.8 $M_{by}$ (hogging)＋0.6 $M_{ty}$;
(10) 0.8 $M_{by}$ (sagging)＋0.6 $M_{ty}$;
(11) 0.6 $M_{by}$ (hogging)＋0.8 $M_{ty}$;
(12) 0.6 $M_{by}$ (sagging)＋0.8 $M_{ty}$.

## 4 Structural Modeling

### 4.1 General requirements

4.1.1 The global ship model is to contain all structural members of shell plating, longitudinal/transverse bulkheads, deck structure, cross-deck, struts, etc., of the hull structure.
4.1.2 The relevant requirements for model element and mesh scantling are given in Section 5, Chapter 1 of this PART.
4.1.3 In general, the following areas are to be subject to fine mesh analysis:
(1) interior angle in connection of the front end bulkhead of cross deck of twin-hull craft (or web beams) to twin hulls;
(2) interior angle in connection of the after end bulkhead of cross deck of twin-hull craft (or web beams) to twin hulls;
(3) positions in the actual structural shape that can not be expressed truly in any coarse mesh model;
(4) other areas where the stress considered for the global coarse mesh model exceeds 95% of the allowable stress.
4.1.4 During the fine mesh analysis, the mesh size of elements in refined area is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth.

### 4.2 Boundary conditions

4.2.1 For global FE model under an equilibrium condition, the boundary supports and constraint conditions given in Table 4.2.1 and Figure 4.2.1 may be used.

**Boundary Conditions of Global FE Model** **Table 4.2.1**

| Position | Displacement constraint | | | Rotation constraint | | |
|---|---|---|---|---|---|---|
| | $\delta_x$ | $\delta_y$ | $\delta_z$ | $\theta_x$ | $\theta_y$ | $\theta_z$ |
| Supporting point *A* | Cons. | Cons. | Cons. | – | – | – |
| Supporting point *B* | – | Cons. | Cons. | – | – | – |
| Supporting point *C* (*C'*) | – | – (Cons.) | Cons. (–) | – | – | – |

Notes:
① The combination of *A*, *B*, *C'* is used for torsion condition, of which the point *C'* position in *z* direction is at wet deck of the cross-deck longitudinal centerline.
② In the case of longitudinal bending condition, the disequilibrium (if any) of force system in *z* direction may cause reaction of the additional supports in way of point *A* and point *B*. In this case, the results in way of point *A* and point *B* are to be neglected (such condition is for midship region only).

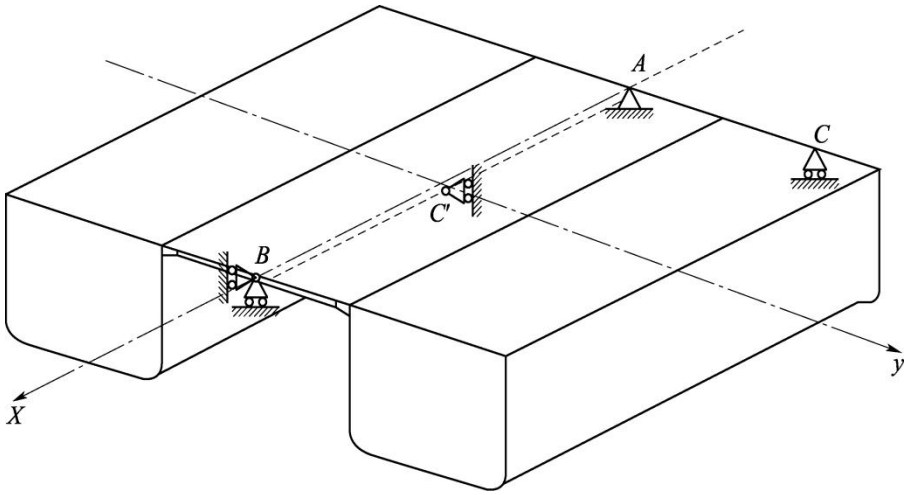



**Figure 4.2.1**

## 5 Yielding Strength Assessment

### 5.1 Permissible stress

5.1.1 The permissible stress is given in Table 5.1.1.

**Permissible Stress** **Table 5.1.1**

| Structural component | Equivalent stress $[\sigma_e]$ (N/mm$^2$) | Shear stress $[\tau]$ (N/mm$^2$) |
|---|---|---|
| Plate element | 200/$K$ | 90/$K$ |

Note: $K$— material factor.

5.1.2 If meshes finer than those specified in Section 5, Chapter 1 of this Chapter are used, the average stress value of all fine meshes under the specified mesh size is to be taken.

5.1.3 Where the loads are applied in accordance with 2.2.1 to 2.2.3 of this Appendix, the equivalent stress of plate element within fine mesh area is not to be greater than $1.2\times235/K$ ($K$ is material factor). Where the loads are applied through equivalent design wave in 2.2.4 of this Appendix, the equivalent stress of plate element within fine mesh area is not to be greater than $1.5\times235/K$ ($K$ is material factor).

## 6 Buckling Strength Assessment

### 6.1 General requirements

6.1.1 The requirements for buckling strength assessment are given in Appendix 1, Chapter 5 of this PART.

# CHAPTER 19 SAND CARRIERS

## Section 1 GENERAL PROVISIONS

### 19.1.1 Application

19.1.1.1 This Chapter applies to self-discharging sand carriers (hereinafter referred to as sand carriers), with the transverse section of typical sand carriers given in Figures 19.1.1.1(1) and 19.1.1.1(2).




Figure 19.1.1.1(1)

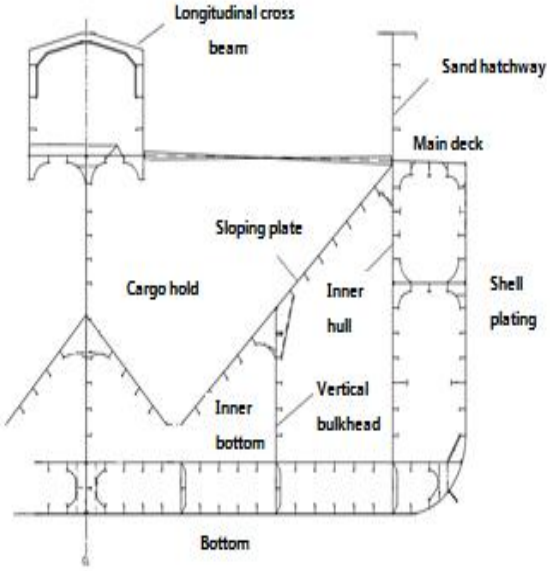



Figure 1 9.1.1.1(2)

19.1.1.2 This Chapter applies to the sand carriers with the main dimensions of $B/D \leq 3.5$.

19.1.1.3 For those not covered in this Chapter, the relevant requirements of Chapter 14 and Chapter 2 of this PART, as applicable, are also to be complied with.

## Section 2 SPECIAL REQUIREMENTS FOR STRUCTURES WITHIN SAND CARGO HOLD REGION

### 19.2.1 Sloping plate and its supporting structure

19.2.1.1 One bulkhead is to be provided under each sloping plate (at port and starboard), respectively for cargo hold fitted with sloping plates complying with the requirements of watertight bulkhead. The sloping structure of cargo hold is to meet the applicable requirements for hopper bulkheads in Chapter 14 of this PART and be in compliance with the requirements for hopper tanks in Chapter 8 of this PART.

19.2.1.2 The sectional area of bulkhead stiffeners or vertical webs with attached plating (bulkhead plating) is to comply with the requirements for pillars in Section 10, Chapter 2 of this PART. In calculation of the load $P$ supported by pillars, $P_0$ is to be taken as the mud volumetric weight acting on sloping plate above within the loaded area $a \times b$.

19.2.1.3 For strength check of pillar under sloping plate, the mud volumetric weight acting on its above or the mud volumetric weight on hatch coamings and sloping plate supported by stiffeners is to be considered.

### 19.2.2 Bottom floors

19.2.2.1 For cargo hold structures in 19.2.1.1 above, the strength of bottom floors may be checked in accordance with the requirements of 14.5.2.1 of Section 5, Chapter 14 of this PART.

19.2.2.2 Vertical stiffeners are to be provided on web of solid floors for supporting pillars under sand hold sloping plate between side longitudinal bulkheads and centerline, with the same thickness as that of the floor and 100 mm in width, both ends are to be snipped, see Figure 19.2.2.2.

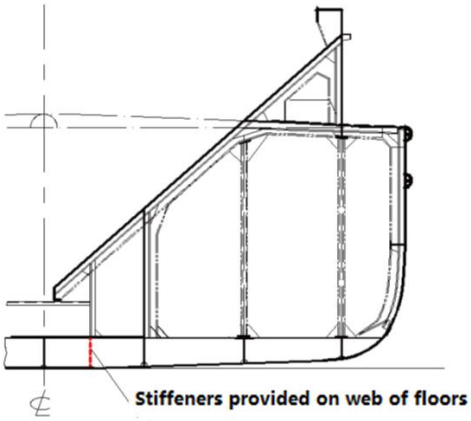



**Figure 19.2.2.2 Stiffeners provided on web of floors**

CHINA CLASSIFICATION SOCIETY

# RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

## 2024

## PART THREE
## MACHINERY INSTALLATIONS

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# CHAPTER 1 GENERAL

## Section 1 GENERAL REQUIREMENTS

**1.1.1 Applications**

1.1.1.1 Main propulsion and auxiliary machinery installations together with their associated equipment, boilers, pressure vessels, pumping and piping systems, and gearing fitted in ships are to comply with the relevant requirements prescribed in this PART.

1.1.1.2 In addition, the machinery installations are to comply with the applicable requirements of PART ONE of the Rules.

**1.1.2 Plans and documents**

1.1.2.1 Prior to the commencement of ship construction, plans and documents as listed in the respective Chapters of this PART are to be submitted for approval. Other plans and documents may be required to be submitted as deemed necessary for individual cases.

1.1.2.2 Any major alterations to basic design, materials or other aspects of the approved plans are to be re-submitted for approval.

## Section 2 GENERAL PROVISIONS

**1.2.1 Ambient conditions**

1.2.1.1 The main and auxiliary engines, shafting and essential machinery equipment are to be so designed, type-selected and arranged as to ensure normal operation under the inclination conditions as shown in Table 1.2.1.1. Considering the type, size and service conditions of the ship, smaller angles of inclination may be permitted.

**Angle of inclination of ships** **Table 1.2.1.1**

| Installations and equipment | Angle of inclination① (°) | | | |
|---|---|---|---|---|
| | Athwartships | | Fore-and-aft | |
| | static | dynamic | static | dynamic |
| Main and auxiliary machinery | 15 | 22.5 | 5② | 7.5 |
| Safety equipment: e.g. emergency power installations, emergency fire pumps and their device | 22.5③ | 22.5③ | 10 | 10 |

Notes: ① Athwartships and fore-and-aft inclinations may occur simultaneously.

② Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as 500/L degrees, where L = length of the ship, in m.

③ For ships carrying liquefied gases and chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

1.2.1.2 The essential machinery installations of ships are to be so designed and arranged as to ensure normal operation under the ambient temperature conditions as shown in Table 1.2.1.2. For ships in restricted service, ambient temperature may be taken according to the actual condition of navigation area.

**Ambient temperature** **Table 1.2.1.2**

| Environment | Location | Temperature range (℃) |
|---|---|---|
| Air | In enclosed spaces | 0 to 45 |
| | Within specific space or on machinery installations | According to actual temperature of specific space or equipment |
| | On the open deck | -25 to 45 |
| Seawater | All positions | 32 |

1.2.1.3 For the purpose of determining the rating of main and auxiliary reciprocating internal combustion engines, the following ambient reference conditions apply to ships for unrestricted service:

| | |
|---|---|
| Total barometric pressure | 0.1 MPa |
| Air temperature | 45℃ |
| Relative humidity | 60% |
| Sea water temperature (charge air coolant-inlet) | 32℃ |

The engine manufacturers are not expected to provide simulated ambient reference conditions at a test bed.

1.2.1.4 In the case of ships for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service.

### 1.2.2 Vibration

1.2.2.1 The propulsion installations are to be so designed, constructed and installed that any mode of their vibrations is not to cause undue stresses in them in the normal operating ranges.

### 1.2.3 Astern power

1.2.3.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolution.

1.2.3.2 Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolution for a period of at least 15 min. The astern trial is to be limited to 30 min or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

1.2.3.3 For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of propulsion machinery.

1.2.3.4 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics.

The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these are to be included in the test plan①.

1.2.3.5 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials②.

### 1.2.4 Overload power

1.2.4.1 Prime movers of main engines and electric generators are to be capable of running at an overload power corresponding to 110% of its rated power.

---

① This regulation applies to:

(1) Ships the contract for construction was signed on or after 1 July 2018.

(2) On or after 1 July 2018, the astern test for the ships other than those in (1) above is to comply with the relevant requirements of 5.5.4.4 of Section 5, Chapter 5 of Rules for Classification of Sea-Going Ships engaged on Domestic Voyages.

② Same as ①.

### 1.2.5 Dead ship starting

1.2.5.1 Ship's machinery is to be so arranged that it can be brought into operation from the dead ship condition using only the facilities available on board without external aid.

Dead ship condition is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.

Where the emergency source of power is an emergency generator which complies with 9.5.3 of this PART and 2.2.1.6 of PART FOUR of the Rules, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

Where there is no emergency generator installed or an emergency generator does not comply with the above-mentioned requirements, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor.

The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 min of a dead ship condition. For steam main propulsion unit, 30 min means time from dead ship condition to successful ignition of first main boiler.

1.2.5.2 1.2.5.1 is not applicable to:

(1) cargo ships with and under coastal service and passenger ships in sheltered water service;

(2) cargo ships of less than 500 gross tonnage.

### 1.2.6 Materials

1.2.6.1 The materials used in the construction of main components for main propulsion and auxiliary machinery installations and propulsion shafting systems, boilers and pressure vessels are to be in compliance with the relevant requirements of CCS Rules for Materials and Welding.

1.2.6.2 For all ships, new installation of materials which contain asbestos are prohibited.

### 1.2.7 Fuel

1.2.7.1 The flash point (closed cup test) of oil fuel for the main propulsion machinery and prime movers to drive generators or boilers are, in general, not to be less than 60℃ For the prime movers of emergency generators, oil fuel having a flash point of not less than 43℃ is permissible.

1.2.7.2 For ships in restricted service, the use of oil fuel having a flashpoint of less than 60℃ but not less than 43℃ may be permitted if the ambient temperature of the space for storage and use of fuel oil may be limited at 10℃ lower than the flashpoint of the fuel oil by special measures.

1.2.7.3 The use of oil fuel having a flashpoint of less than 60℃ but not less than 43℃ may be permitted (e.g. for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A) subject to the following:

(1) fuel oil tanks except those arranged in double bottom compartments are to be located outside of machinery spaces of category A;

(2) provision for the measurement of oil temperature are to be provided on the suction pipe of the oil fuel pump;

(3) stop valves and/or cocks are provided on the inlet side and outlet side of the oil fuel strainers;

(4) pipe joints of welded construction or of circular cone type or spherical type union joint are to be applied as much as possible;

(5) the whole fuel system is to be located outside the machinery spaces of category A;

(6) the arrangement of fuel oil tank is to comply with the requirements of 3.2.1.5(1)-(5) of Chapter 3 of PART SIX of Rules for Classification of Sea-Going Steel Ships.

1.2.7.4 In cargo ships the use of fuel having a lower flashpoint than 43℃ may be permitted provided that such fuel is not stored in any machinery space and the arrangement for the complete installation has been submitted for approval.

1.2.7.5 Ships using distillates with a sulphur content not more than 0.10% m/m are to comply

with the relevant requirements of this PART and in addition, the requirements of CCS Guidelines for Use of Low Sulphur Distillate Fuels in Ships.

**1.2.8 Emission treatment**

1.2.8.1 Ships installed with exhaust gas cleaning systems (hereinafter referred to as the EGC systems) for reduction of SOx emission from fuel oil combustion units are, in addition to the relevant provisions of this PART, to comply with the requirements of CCS Guidelines for Testing and Survey of Exhaust Gas Cleaning Systems and Guidelines for Design and Installation of Exhaust Gas Cleaning Systems.

1.2.8.2 Ships installed with selective catalytic reduction systems (hereinafter referred to as the SCR systems) for reduction of NOx emission from diesel engines are, in addition to the relevant provisions of this PART, to comply with the requirements of CCS Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) systems and Guidelines for Application of Selective Catalytic Reduction (SCR) Systems Onboard Ships.

**1.2.9 Clean energy and power**

1.2.9.1 Ships other than liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Rules for Natural Gas Fuelled Ships.

1.2.9.2 Liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers.

1.2.9.3 Liquefied gas carriers using liquefied gas other than natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of 16.9, Chapter 16, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

1.2.9.4 Ships using methyl/ethyl as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Guidelines for Ships Using Methanol/Ethanol Fuel.

1.2.9.5 Ships using biodiesel fuel or the mixture of biodiesel and regular fuel as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of Pt. 3 of the Guidelines for Ships Using Alternative Fuel.

1.2.9.6 Ships provided with the fuel cell power system are, in addition to the relevant provisions of this PART, to comply with relevant requirements of Pt. 2 of the Guidelines for Ships Using Alternative Fuel.

**1.2.10 Trials**

1.2.10.1 The mooring and sea trials for machinery installations are to be carried out in accordance with the relevant provisions of the Rules and the approved test programs.

On completion of the trials, corresponding technical documents and trial reports are to be furnished by the shipyard.

## Section 3 ARRANGEMENT

**1.3.1 Means of escape**

1.3.1.1 Means of escape in machinery spaces are to comply with the requirements specified in Chater 2-2, PART FOUR of Technical Regulations for the Statutory Surveys of Sea-Going Ships engaged on Non-International Voyages.

**1.3.2 Boiler arrangement**

1.3.2.1 Where boilers are located in machinery spaces on tween-decks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the tween-decks are to be provided with coamings at least 200 mm in height to prevent the oily water that might leak from spreading and dropping to the lower level. This area may be drained to the bilges. The drain tank is not to form part of an overflow system.

1.3.2.2 The clearance between boilers and fuel oil tank boundaries is not to be less than that specified in Table 1.3.2.2.

For cargo ships of less than 500 gross tonnage, the distance specified in the Table may be decreased appropriately if effective thermal insulation measures are adopted.

**The clearance between boilers and fuel oil tank boundaries (mm) Table 1.3.2.2**

| | | Top plate of double-bottom fuel oil tank | Fuel oil bulkhead |
|---|---|---|---|
| Water-tube boiler | Outer wall | — | 450 |
| | Bottom | 600 | — |
| Fire-tube boiler | End plate | — | 600 |
| | Bottom | 450 | — |

### 1.3.3 Skylights of machinery casings

1.3.3.1 Skylights located in machinery spaces of category A are to be of steel and are not to contain glass panels. Suitable arrangements are to be made to permit the release of smoke in the event of fire, from the space to be protected.

### 1.3.4 Ventilation

1.3.4.1 Machinery spaces are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

1.3.4.2 All spaces, where flammable or toxic gases or vapors may accumulate, are to be provided with adequate ventilation.

### 1.3.5 Position of emergency equipment on passenger ships

1.3.5.1 Emergency sources of electrical power, fire pumps, bilge pumps except those specifically serving the spaces forward of the collision bulkhead, any fixed fire-extinguishing system required in the Rules and other emergency installations which are essential for the safety of the ship, except anchor windlasses, are not to be installed forward of the collision bulkhead.

### 1.3.6 Protection

1.3.6.1 In places where the working of machinery and equipment may cause injuries to the operating personnel, handrails, protecting casings or screens are to be provided.

1.3.6.2 Placards or labels are to be provided for illustrating the correct procedures of operation, so as to avoid any mistakes in the operation or change-over of the machinery or systems.

1.3.6.3 All surfaces of machinery and pipes where the hot surfaces may injure personnel are to be protected by handrails or shields. Where the surface temperature may exceed 220℃, they are to be effectively shielded to prevent ignition caused by flammable liquids. Where the insulation covering these surfaces is oil-absorbing or previous to oil, such insulation is to be encased in steel or equivalent.

### 1.3.7 Communication

1.3.7.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the engines are normally controlled: one of these is to be an engine-room telegraph which provides visual indication of the orders and responses both in the machinery space and in the navigation bridge. Appropriate means of communication is to be provided from the navigation bridge and the engine-room to any other positions from which the speed of direction of thrust of the propellers may be controlled.

### 1.3.8 Accessibility

1.3.8.1 Accessibility, for the purposes of control, maintenance, inspection and repair of various machinery and equipment, is to be provided in machinery and boiler spaces.

### 1.3.9 Stuffing boxes for shaftings

1.3.9.1 Stuffing boxes are to be fitted on the watertight bulkhead of the engine room where the shafts pass through. They are to be so arranged as to be convenient for tightening and renewing

the packings from the engine room side. The fore sealing ends of the stern tubes as well as the plummer blocks are to be easily accessible for maintenance.

### 1.3.10 Earthing

1.3.10.1 Suitable earthing arrangements are to be provided to prevent excessive electrical potential difference between the crankshaft/shafting of main propulsion diesel engines and hull.

# CHAPTER 2 PUMPING AND PIPING SYSTEMS

## Section 1 GENERAL PROVISIONS

### 2.1.1 General requirements

2.1.1.1 Unless otherwise stated, this Chapter applies to piping systems of all ships. Chemical cargo piping, chemical process piping, liquefied gases cargo piping and liquefied gases process piping are to comply with relevant requirements in CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk and CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk respectively.

### 2.1.2 Plans and documents

2.1.2.1 For all ships, the following plans and documents are to be submitted for approval:

(1) arrangement of machinery and boiler spaces;
(2) bilge piping and ballast piping;
(3) arrangement of air pipes, sounding pipes and overflow pipes;
(4) fuel oil feeding system for main and auxiliary engines and boilers;
(5) fuel oil transfer system;
(6) lubricating oil piping for main and auxiliary engines;
(7) cooling water piping system for main and auxiliary engines;
(8) compressed air piping system;
(9) steam piping;
(10) condensate and exhaust steam piping;
(11) boiler feed and blow-off piping;
(12) oil fuel heating piping;
(13) purgative system for fuel oil and lubricating oil;
(14) exhaust gas piping for main and auxiliary engines;
(15) arrangement of ventilation pipes for engine room;
(16) hydraulic systems;
(17) arrangement of drain pipes;
(18) additional plans and documents as may be deemed necessary.

2.1.2.2 For oil tankers, the following plans and documents are to additionally be submitted for approval:

(1) cargo oil piping system;
(2) bilge piping system of cargo pump rooms and cofferdams;
(3) cargo oil heating piping;
(4) arrangement of venting systems (including purge, gas-free systems);
(5) closed ullage system (where applied);
(6) arrangement of cargo pump tank.

2.1.2.3 For all ships, the following plans and documents are to be submitted for information (if relevant information is reflected in the submitted plans, submission of following plans and documents is not necessary):

(1) specifications of machinery installations;
(2) particulars of machinery equipment;
(3) calculations of machinery equipment.

2.1.2.4 The materials, sizes, types, design pressures and design temperatures of pipes, valves and fittings, and the set pressure of safety valves are to be clearly marked on plans. Where separate calculations are not submitted, necessary rule calculations are to be affixed to the plans.

### 2.1.3 Design pressure

2.1.3.1 The design pressure for piping is the maximum permissible working pressure and it is not to be less than the highest set pressure of any safety valve or relief valve.

2.1.3.2 For pipes containing fuel oil, the design pressure is to be taken as given in Table 2.1.3.2.

**Design pressure for pipes containing fuel oil** **Table 2.1.3.2**

| Working temperature / Working pressure | $T \leq 60℃$ | $T > 60℃$ |
|---|---|---|
| $P \leq 0.7$MPa | 0.3 MPa or highest working pressure, whichever is greater | 0.3 MPa or highest working pressure, whichever is greater |
| $P > 0.7$MPa | Highest working pressure | 1.4 MPa or highest working pressure, whichever is greater |

2.1.3.3 For special cases, the design pressure is to be specially considered.

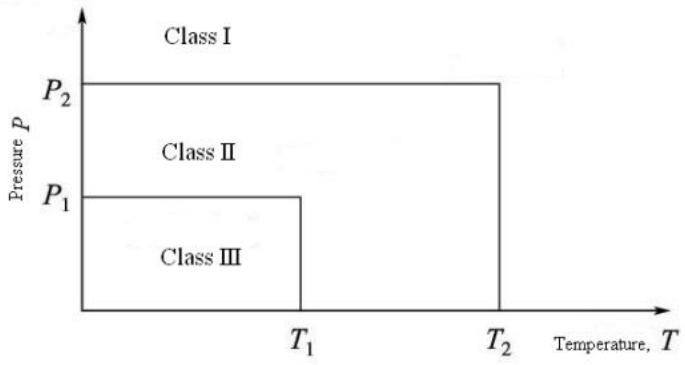
### 2.1.4 Design temperature

2.1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid. In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15℃ above the designed temperature are expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess. For special cases, the design temperature is to be specially considered.

### 2.1.5 Classes of pipes

2.1.5.1 For the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure, pressure piping systems are divided into three classes in accordance with their design pressure and design temperature, as indicated in Table 2.1.5.1.

**Piping system class** **Table 2.1.5.1**




| Piping system | Class I | | Class II | | Class III | |
|---|---|---|---|---|---|---|
| | Design pressure $> P_2$ (MPa) | Design temperature $> T_2$ (℃) | Design pressure $\leq P_2$ (MPa) | Design temperature $\leq T_2$ (℃) | Design pressure $\leq P_1$ (MPa) | Design temperature $\leq T_1$ (℃) |
| Steam | ＞1.6 | or ＞300 | ≤1.6 | and ≤300 | ≤0.7 | and ≤170 |
| Thermal oil | ＞1.6 | or ＞300 | ≤1.6 | and ≤300 | ≤0.7 | and ≤150 |
| Fuel oil, lub-oil, flammable hydraulic oil | ＞1.6 | or ＞150 | ≤1.6 | and ≤150 | ≤0.7 | and ≤60 |
| Other media | ＞4.0 | or ＞300 | ≤4.0 | and ≤300 | ≤1.6 | and ≤200 |

Notes:

① For Class I piping, one parameter for design pressure and design temperature of Class I specified in the Table is to be met; For Class II piping, one parameter for design pressure and design temperature of Class II specified in the Table is to be met; For Class III piping, two parameters are not to exceed the provisions of Class III the Table.

② Toxic or corrosive media, flammable media heated above flash point or with flash point below

60℃ media and liquefied gas belong to class I. If means of special safeguards for preventing leakage and its consequences are provided (e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening etc.), they may also belong to class II, but except toxic media.
③ Cargo pipes belong to class III.
④ Class III pipes may be used for open ended piping, e.g. drains, overflows, vents boiler waste steam pipes, etc.
⑤ Other media mean air, gases, water, and non-flammable hydraulic oil.
⑥ Thermal oil means the circulating oil used in the thermal oil system as specified in Section 8, Chapter 4 of this PART.

### 2.1.6 Materials

2.1.6.1 Materials to be used for pipes, valves and fittings are to be suitable for the medium and service for which the piping is intended. In the case of especially corrosive media, the material for the piping system is to be taken into consideration in each particular case.
2.1.6.2 Material for pipes, valves and relative fittings belonging to Classes I and II and for valves and pipes fitted on the ship's side and for valves fitted on the collision bulkhead are to be tested in accordance with the relevant requirements of CCS Rules for Materials and Welding.
2.1.6.3 Materials for pipes, valves and fittings of Class III are to be tested in accordance with applicable standards.

## Section 2 CARBON, LOW ALLOY STEELS AND STAINLESS STEELS

### 2.2.1 Carbon and low alloy steel pipes, valves and fittings

2.2.1.1 Classes I and II pipes are to be seamless steel pipes or welded pipes fabricated with an approved welding procedure.
2.2.1.2 In general, carbon and carbon-manganese steel pipes, valves and fittings are not to be used for medium temperatures above 400℃. Nevertheless, they may be used for higher temperatures if their metallurgical behavior and time dependent strength (UTS after 100,000 h) are in compliance with national or international codes or standards and if such values are guaranteed by the steel manufacturer.
Special alloy steel pipes, valve and fittings are to be employed according to the relevant requirements of CCS Rules for Materials and Welding.

### 2.2.2 Calculation of wall thickness

2.2.2.1 The minimum wall thickness ( of steel pipes subject to internal pressure is not to be less than that determined by the following formula[①]:

$$\delta=\delta_o + b + c \qquad \text{mm}$$

where: δ0 — the basic wall thickness, in mm, see 2.2.2.2 of this Section;
b — allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.2.2.3 of this Section;
c — corrosion allowance, in mm, to be obtained from Table 2.2.2.1.
For pipes passing through tanks, an additional corrosion allowance is to be taken, depending on the external medium, in order to account for the external corrosion. Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the corrosion allowance may be reduced by not more than 50%. In the case of use of special alloy steel with sufficient corrosion resistance, the corrosion allowance may be reduced, even to zero.

① This formula applies to pipes the external and internal diameter ratio of which not exceeding 1.7.

**Corrosion allowance C for steel pipes** **Table 2.2.2.1**

| Usage of piping | *C* | Usage of piping | *C* |
|---|---|---|---|
| Overheat steam piping | 0.3 | Lubricating oil piping | 0.3 |
| Saturated steam piping | 0.8 | Fuel oil piping | 1.0 |
| Steam heating piping in cargo tank | 2.0 | Cargo oil piping | 2.0 |
| Boiler open-type feed piping | 1.5 | Refrigerant piping of refrigerating installation | 0.3 |
| Boiler close-type feed piping | 0.5 | Fresh water piping | 0.8 |
| Boiler blow-off piping | 1.5 | Sea water piping | 3.0 |
| Compressed air piping | 1.0 | Salt water piping in refrigerated hold | 2.0 |
| Hydraulic oil piping | 0.3 | | |

2.2.2.2 The basic wall thickness δ0 for steel pipes is to be determined by the following formula:

$$\delta_o = pD/(2[\sigma]e+p) \qquad \text{mm}$$

where: $p$ — design pressure, in MPa, see 2.1.3 of this Chapter;
$D$ — outside diameter of steel pipes, in mm;
［σ］ — permissible stress of steel pipes, in N/mm2, see 2.2.2.4 of this Section;
e — welding efficiency factor. For seamless steel pipes and electric resistance or induction welded steel pipes, e is to be taken as 1; for pipes made by other methods, e will be specially considered.

2.2.2.3 Bending allowance b is not to be less than that determined by the following formula:

$$b = 0.4\frac{D}{R}\delta_o \qquad \text{mm}$$

where: $R$ — radius of curvature of a pipe bend at the centre line of the pipe, in mm, in general, R is not to be less than 3D;
$D$ — outside diameter of steel pipes, in mm;
δ0 — basic wall thickness, in mm, see 2.2.2.2 of this Section.

2.2.2.4 Permissible stress ［σ］ of steel pipes is to be taken as the lowest of the following values:

$$[\sigma] = \frac{R_m}{2.7} \qquad \text{N/mm}^2$$

$$[\sigma] = \frac{R_{eH}^T}{1.6} \qquad \text{N/mm}^2$$

$$[\sigma] = \frac{\sigma_D^T}{1.6} \qquad \text{N/mm}^2$$

$$[\sigma] = \sigma_c^T \qquad \text{N/mm}^2$$

where: $R_m$— tensile strength of material at room temperature, in N/mm$^2$;

$R_{eH}^T$ — yield stress or 0.2% proof stress ($R_{p0.2}$) of material at design temperature, in N/mm$^2$;

$\sigma_D^T$ — average stress of material to produce rupture in 100,000 h at design temperature, in N/mm$^2$;

$\sigma_c^T$ — average stress to produce 1% creep in 100,000 h at the design temperature, in N/mm$^2$;

$R_m$, $R_{eH}^T$, $\sigma_D^T$ are to comply with the relevant requirements of CCS Rules for Materials and Welding. National or international standards may be accepted for $R_{eH}^T$ . $\sigma_c^T$ may be used as appropriate based on reliable conditions if it is deemed necessary.

2.2.2.5 The minimum wall thickness δ mentioned in 2.2.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness $\delta_m$ of pipes is not to be less than that determined by the following formula:

$$\delta_m = \frac{\delta}{1 - \frac{a}{100}} \qquad \text{mm}$$

where: $a$ — percentage of negative manufacturing tolerance on thickness.

2.2.2.6 Where the minimum thickness calculated by the formula specified in 2.2.2.5 is less than that shown in Table 2.2.2.6(1), Table 2.2.2.6(2) or Table 2.2.2.6(3), the minimum nominal thickness for the appropriate standard pipe size shown in the Tables is to be used.

For threaded pipes, the thickness is to be measured at the bottom of the thread.

**External diameter and minimum nominal thickness for steel pipes, in mm Table 2.2.2.6(1)**

| External diameter, D | Minimum nominal thickness (δ) | | | |
|---|---|---|---|---|
| | General pipe③④⑥⑧⑨⑩ | Air pipe, overflow pipe and sounding pipe of tank related to hull structure①②③④⑥⑦⑧ | Bilge and ballast pipe, general sea water pipe and steam heating coil in liquid tank①③④⑤⑥⑦⑧ | Bilge pipe, air pipe, overflow pipe and sounding pipe through ballast tank and fuel oil tank. Ballast pipe through fuel oil tank and fuel oil pipe through ballast tank①②③④⑤⑥⑦⑧ |
| 10.2～12 | 1.6 | | | |
| 13.5～19.3 | 1.8 | | | |
| 20 | 2.0 | | | |
| 21.3～25 | 2.0 | | 3.2 | |
| 26.9～33.7 | 2.0 | | 3.2 | |
| 38～44.5 | 2.0 | 4.5 | 3.6 | 6.3 |
| 48.3 | 2.3 | 4.5 | 3.6 | 6.3 |
| 51～63.5 | 2.3 | 4.5 | 4.0 | 6.3 |
| 70 | 2.6 | 4.5 | 4.0 | 6.3 |
| 76.1～82.5 | 2.6 | 4.5 | 4.5 | 6.3 |
| 88.9～108 | 2.9 | 4.5 | 4.5 | 7.1 |
| 114.3～127 | 3.2 | 4.5 | 4.5 | 8.0 |
| 133～139.7 | 3.6 | 4.5 | 4.5 | 8.0 |
| 152.4～168.3 | 4.0 | 4.5 | 4.5 | 8.8 |
| 177.8 | 4.5 | 5.0 | 5.0 | 8.8 |
| 193.7 | 4.5 | 5.4 | 5.4 | 8.8 |
| 219.1 | 4.5 | 5.9 | 5.9 | 8.8 |
| 244.5～273 | 5.0 | 6.3 | 6.3 | 8.8 |
| 298.5～368 | 5.6 | 6.3 | 6.3 | 8.8 |
| 406.4～457 | 6.3 | 6.3 | 6.3 | 8.8 |

Notes:

① Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the minimum wall thickness may be reduced by an amount up to 1 mm.

② For sounding pipes, except those for cargo tanks with cargo having a flash point less than 60℃, the minimum wall thickness is intended to apply to the part outside the tank.

③ For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.
④ The external diameters and thicknesses have been selected from ISO Recommendations R336 for welded and seamless steel pipes. For pipes covered by other Standards, slightly reduced thicknesses may be accepted.
⑤ The minimum wall thickness for bilge lines and ballast lines through deep tanks will be subject to special consideration. The minimum wall thickness for ballast lines through cargo tanks is not to be less than that specified in Table 5.3.4.2 of Section 3, Chapter 5 of this PART.
⑥ The minimum wall thickness for pipes larger than 457 mm nominal size is to be in accordance with a national or international standard and in any case not less than the minimum wall thickness of the appropriate column indicated for 406.4 to 457 mm pipe size in Table 2.2.2.6(1).
⑦ The minimum internal diameters of bilge, sounding, air and overflow pipes are to be:

| | |
|---|---|
| Bilge | 50 mm |
| Sounding | 32 mm |
| Air and overflow | 50 mm |

⑧ In general, the minimum thickness listed in this Table is the nominal wall thickness and no allowance need be made for negative tolerance and reduction in thickness due to bending.
⑨ The minimum wall thickness of exhaust gas pipe will be subject to special consideration.
⑩ The minimum wall thickness for cargo oil lines will be subject to special consideration.

**External diameter and minimum nominal thickness δ for stainless steel pipes, in mm**

**Table 2.2.2.6(2)**

| External diameter (D) | Minimum nominal thickness (δ) |
|---|---|
| ≤10 | 1.0 |
| 11～18 | 1.5 |
| 19～83 | 2.0 |
| 84～169 | 2.5 |
| 170～246 | 3.0 |
| 247～340 | 3.5 |
| 341～426 | 4.0 |
| 427～511 | 4.5 |
| 512～597 | 5.0 |

**External Diameter and Minimum Nominal Wall Thickness for Austenitic Stainless Steel Pipes, in mm**

**Table 2.2.2.6(3)**

| External diameter (D) | Minimum nominal wall thickness (δ) |
|---|---|
| 10.2 ～ 17.2 | 1.0 |
| 21.3 ～ 48.3 | 1.6 |
| 60.3 ～ 88.9 | 2.0 |
| 114.3 ～ 168.3 | 2.3 |
| 219.1 | 2.6 |
| 273.0 | 2.9 |
| 323.9 ～ 406.4 | 3.6 |
| >406.4 | 4.0 |
| Note: Diameters and thicknesses according to national or international standards may be accepted. | |

2.2.2.7 The minimum wall thickness of the scuppers and discharge pipes is to comply with the relevant requirements of regulation 2.11 of Chapter 2, PART THREE of Technical Regulations for

the Statutory Surveys of Sea-Going Ships engaged on Non-International Voyages.

2.2.2.8 The minimum wall thickness of air pipes above the weather deck is to comply with the relevant requirements of 1.8.7.5 of PART TWO of the Rules.

# Section 3 COPPER AND COPPER ALLOYS

### 2.3.1 Copper and copper alloy pipes, valves and fittings

2.3.1.1 Copper and copper alloy pipes used in Classes I and II piping systems are to be seamless.

2.3.1.2 Materials of copper and copper alloys for Class III piping systems are to be manufactured and tested in accordance with the approved standards.

2.3.1.3 In general, copper and copper alloy pipes, valves and fittings are not be used for media having a temperature above the following limits:

copper and aluminum brass: 200℃;

copper nickel: 300℃;

special bronze suitable for high temperature services: 260℃.

### 2.3.2 Calculation of wall thickness

2.3.2.1 The minimum wall thickness δ of copper and copper alloy pipes subject to internal pressure is not to be less than that determined by the following formula①:

$$\delta=\delta_0 + b + c \qquad \text{mm}$$

where: $\delta_0$ — the basic wall thickness, in mm, see 2.3.2.2 of this Section;

$b$— allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.3.2.3 of this Section;

$c$— corrosion allowance, in mm; for copper, brass and similar alloys, copper-tin alloys except those with lead contents, and copper-nickel alloys where the nickel content is less than 10%, c = 0.8 mm; copper-nickel alloys where the nickel content is 10% or greater, c = 0.5 mm; where the media are non-corrosive relative to the pipe material, c = 0.

2.3.2.2 The basic wall thickness of copper and copper alloy pipes is to be determined by the following formula:

$$\delta_0 = \frac{pD}{2[\sigma]e + p} \qquad \text{mm}$$

where: $p$ — design pressure, in MPa, see 2.1.3 of this Chapter;

$D$ — outside diameter of pipe, in mm;

$[\sigma]$ — permissible stress, in N/mm$^2$, obtained from Table 2.3.2.2;

$e$ — efficiency factor, $e$ = 1 for seamless copper pipes and for welded copper pipes delivered by manufacturers approved for making welded copper pipes which are considered an equivalent to seamless copper pipes. For copper pipes made by other methods, e will be specially considered.

**Allowable stress of copper and copper alloy pipes [σ]** **Table 2.3.2.2**

| Materials | Material | Tensile | Allowable stress (N/mm2) |
|---|---|---|---|

① This formula applies to pipes the external and internal diameter ratio of which not exceeding 1.7.

| | condition | strength ($N/mm^2$) | Design temperature (℃) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| copper | annealing | 215 | 41 | 41 | 40 | 40 | 34 | 27.5 | 18.5 | — | — | — | — |
| Aluminum brass | annealing | 325 | 78 | 78 | 78 | 78 | 78 | 51 | 24.5 | — | — | — | — |
| copper-nickel alloys CuNi5Fe1Mn CuNi10Fe1Mn | annealing | 275 | 68 | 68 | 67 | 65.5 | 64 | 62 | 59 | 56 | 52 | 48 | 44 |
| copper-nickel alloys CuNi30 | annealing | 365 | 81 | 79 | 77 | 75 | 73 | 71 | 69 | 67 | 65.5 | 64 | 62 |

Notes:
① If the metal temperature is between the values listed in the Table, allowable stress may be determined by linear interpolation.
② The allowable stresses of materials not covered by the Table are to submit detailed information.

2.3.2.3 Bending allowance *b* is not to be less than that determined by the following formula:

$$b=0.4\frac{D}{R}\delta_0 \qquad \text{mm}$$

where: *R* — radius of curvature of a pipe bend at the centre line of the pipe, in mm. In general, R is not to be less than 3 *D*;
*D* — outside diameter of pipe, in mm;
$\delta 0$ — basic wall thickness, in mm, see 2.3.2.2 of this Section.

2.3.2.4 The minimum wall thickness δ mentioned in 2.3.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness of pipes is not to be less than that determined by the following formula:

$$\delta_m=\frac{\delta}{1-\frac{a}{100}} \qquad \text{mm}$$

where: *a* — percentage of negative manufacturing tolerance on thickness.

**External diameter and minimum nominal thickness**
**(m for copper and copper alloy pipes, in mm**

**Table 2.3.2.5**

| Outside diameter (D) | Minimum nominal thickness (δm) | |
|---|---|---|
| | 铜 | 铜 合 金 |
| 8～10 | 1.0 | 0.8 |
| 12～20 | 1.2 | 1.0 |
| 25～44.5 | 1.5 | 1.2 |
| 50～76.1 | 2.0 | 1.5 |
| 88.9～108 | 2.5 | 2.0 |
| 133～159 | 3.0 | 2.5 |
| 193.7～267 | 3.5 | 3.0 |
| 273～470 | 4.0 | 3.5 |
| 508 | 4.5 | 4.0 |

Notes:
① The outside diameters and the thickness have been selected from ISO Standards.
② For pipes covered by other standards, slightly reduced thickness may be accepted.

2.3.2.5 Where the minimum wall thickness calculated by the formula specified in 2.3.2.4 is less than that shown in Table 2.3.2.5, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used.
For threaded pipes, the thickness is to be measured at the bottom of the thread.

# Section 4 OTHER MATERIALS

**2.4.1 Grey cast iron pipes, valves and fittings**

2.4.1.1 Grey cast iron pipes, valves and fittings are not to be used in Class I and Class II piping systems. Grey cast iron valves and fittings may be used in Class II steam piping but the design temperature does not exceed 220℃.

2.4.1.2 Grey cast iron pipes, valves and fittings may, in general, be accepted in Class III piping systems, in cargo lines within cargo tanks of tankers , but grey cast iron is not to be used for the following:

(1) cargo oil pipelines having pressures exceeding 1.6 MPa on weather decks of oil tankers;
(2) pipes, valves and fittings intended for conveying media having temperatures above 220℃;
(3) piping may be subjected to pressure shock, excessive strains and vibration;
(4) ship-side valves and fittings and sea valves, pipes fitted on the ship sides and sea chest;
(5) valves fitted on the collision bulkhead;
(6) valves under static head fitted on the outside of fuel tank walls;
(7) boiler blow-off systems;
(8) pipes for steam, fire extinguishing, bilge and ballast systems.

Grey cast iron may be accepted for pressures up to 1.6 MPa for cargo oil pipe lines on weather decks of oil tankers except for manifolds and their valves and fittings connected to cargo handling hoses.

**2.4.2 Nodular graphite cast iron pipes, valves and fittings**

2.4.2.1 Ferritic nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12% on a gauge length of $5.65\sqrt{S_0}$ , where $S_0$ is the cross-sectional area of the test piece.

2.4.2.2 Ferritic nodular graphite iron pipes, valves and fittings may be accepted for bilge, ballast and cargo oil piping.

2.4.2.3 Ferritic nodular graphite cast iron pipes, valves and fittings are not to be used in piping systems for conveying media having temperatures exceeding 350℃.

2.4.2.4 Where ferritic nodular graphite iron castings are used for ship-side pipes, valves and fittings, the properties of this material are to comply with the relevant requirements of CCS Rules for Materials and Welding.

2.4.2.5 Where the elongation is less than the minimum required in 2.4.2.1 of this Section, the material is to be subject to the same limitations as grey cast iron.

**2.4.3 Plastic pipes**

2.4.3.1 The ranges and locations of plastic pipes used in ships are to comply with the provisions in Table 1 of Appendix I of Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships, and the plastic pipes are to comply with the fire endurance requirements in the Table.

2.4.3.2 Plastic pipes used on ships are to be selected in relation to their chemical composition, physical and mechanical properties, and temperature limits.

2.4.3.3 Plastic pipes are in general not to be used for media with a temperature above 60℃ or below 0℃.

2.4.3.4 Plastic pipes used on ships are to be designed, manufactured, used and test in accordance with the relevant requirements in Table 1 of Appendix I of Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships.

**2.4.4 Flexible hoses**

2.4.4.1 Flexible hoses mean short length of metallic or non-metallic hoses normally with prefabricated end fittings ready for installation.
2.4.4.2 Flexible hoses may be used for a permanent connection between a fixed piping system and items of machinery, as well as temporary connection between portable equipment and pipes.
2.4.4.3 Flexible hoses are to be designed, manufactured, used and tested in accordance with the relevant requirements of Appendix 2 of Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships.

# Section 5 CONNECTION OF PIPE LENGTHS, HEAT TREATMENT AND NON-DESTRUCTIVE TESTING

### 2.5.1 Connection of pipe lengths

2.5.1.1 Direct connection of pipe lengths may be obtained by:
(1) welded butt-joints between pipes or between pipes and valve chests or other fittings, the welded butt-joints are to be of full penetration type with or without special provisions for the quality of root side①;
(2) slip-on sleeve welded joints, the slip-on sleeve welded joints are to have sleeves and relative welding of adequate dimensions conforming to the recognized standard;
(3) threaded sleeve joints of approved type;
(4) mechanical joints.

**Connection of pipe length** **Table 2.5.1.2(1)**

| Type of connection | Allowed for classes | Allowed for outside diameter |
|---|---|---|
| Butt welded joints with special provision for a high quality of root side | I、II、III | No restriction |
| Butt welded joints without special provision for a high quality of root side | II、III | |
| Slip-on sleeve welded joints | III | |
| | I, II, except for piping systems conveying toxic media where fatigue, severe erosion is expected to occur | $D \leq 88.9$ mm |

2.5.1.2 The application of the aforesaid types of connection is as follows:
(1) Welded butt-joints and slip-on sleeve welded joints are to comply with the requirements specified in Table 2.5.1.2(1).
(2) Slip-on threaded joints are to comply with requirements of a recognized standard. Slip-on threaded joints may be used for outside diameters as stated below except for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice is expected to occur. Threaded joints in $CO_2$ systems are to be allowed only inside protected spaces and in $CO_2$ cylinder rooms.
① Threaded joints for direct connectors of pipe lengths with tapered thread may be allowed for Class I, outside diameter not more than 33.7 mm as well as Class II and Class III, outside diameter not more than 60.3 mm.
② Threaded joints for parallel thread may be allowed for Class III, outside diameter not more than 60.3 mm.
③ In particular cases, sizes in excess of those mentioned above may be accepted if they satisfy the requirements of recognized international or national standards.

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① Special provisions for the quality of root side means that butt welding is carried out from both sides or that welding with backing or single side welding charged with inert gas inside is adopted for the first step of welding procedure or by other accepted similar methods.

### 2.5.2 Flange connections

2.5.2.1 Typical flange connections are indicated in Figure 2.5.2.1.

Slip-on joints, sleeve threaded joints and other types of direct connection of pipe lengths (e.g. bell and spigot joints) may be allowed in each particular case for small diameter and depending upon the service conditions.

2.5.2.2 The above-mentioned types of flange connections are to be selected in accordance with the requirements specified in Table 2.5.2.2.

2.5.2.3 The dimensions of flanges and relative bolts are to be chosen in accordance with the national standards or acceptable standards. For special application, the dimensions of flanges and relative bolts are to be subject to special consideration①.

Gaskets are to be suitable for the media being conveyed under design pressure and temperature conditions and their dimensions and configuration are to be in accordance with national or acceptable standards.

Flange connections are to be in accordance with national or international standards that are applicable to the piping system and are to recognize the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

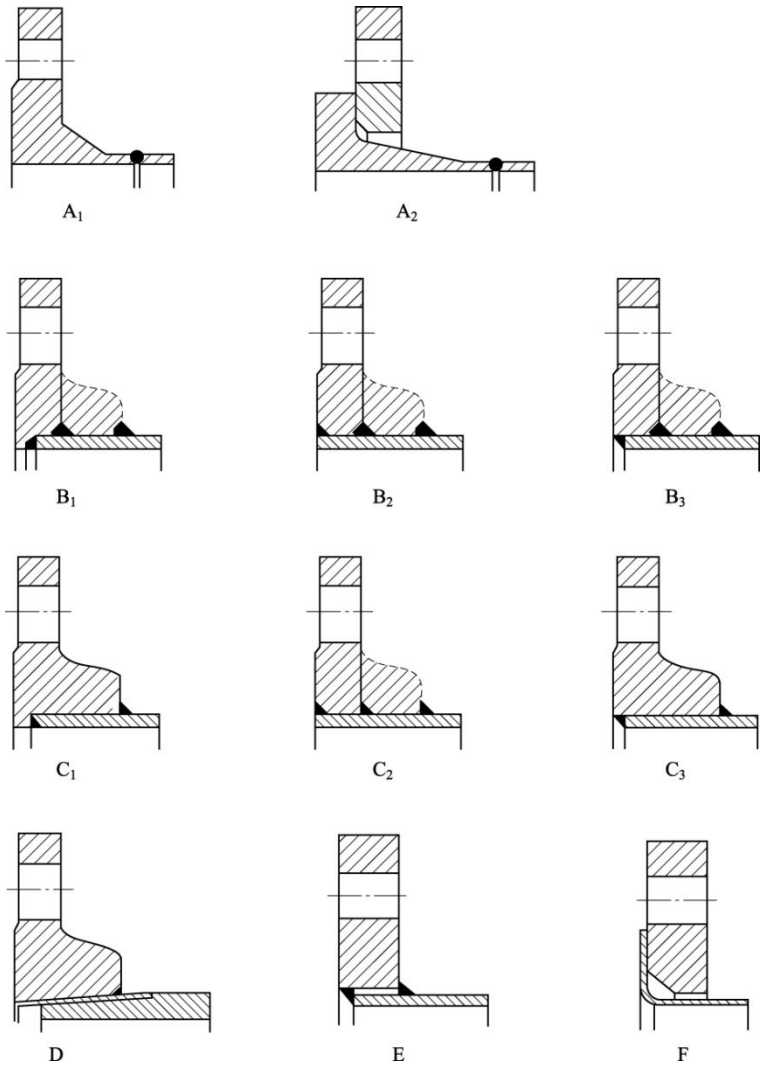



**Figure 2.5.2.1 Typical flange connections**

Notes: ① For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the

① For special application, the dimensions of flanges and bolts are to be completely calculated for flanges the installation temperature, pressure and dimensions of which exceeding a reliable value.

screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. After the flange has been screwed hard home, the pipe is to be expanded into the flange.

② The leg length of the fillet weld and the penetration of the flange edge, as shown in the Figure, are in general to be 1.5 times the wall thickness of the pipe, but not less than 5 mm.

**Application of typical flange connections** **Table 2.5.2.2**

| Piping class | Toxic or corrosive media④, flammable media④, liquefied | Lubricating oil and fuel oil | Steam③ and hot oil | Other media①②③ |
|---|---|---|---|---|
| I | A、B⑥ | A、B | A、B⑥ | A、B |
| II | A、B、C | A、B、C、E⑦ | A、B、C、D⑤、E⑤ | |
| III | | A、B、C、E | A、B、C、D、E | A、B、C、D、E、F② |

Notes:

① Including water, air, other gases, hydraulic oil.

② Type F for water pipes and open ended lines only.

③ Only type A when design temperature exceeds 400℃.

④ Only type A when design pressure exceeds 1 MPa.

⑤ Types D and E are not be used when design temperature exceeds 250℃.

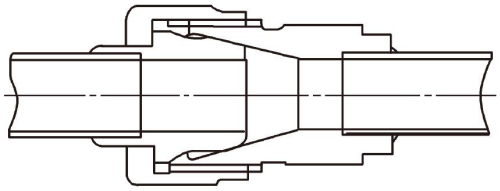
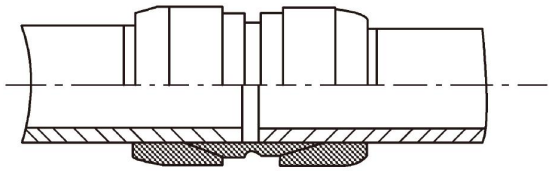
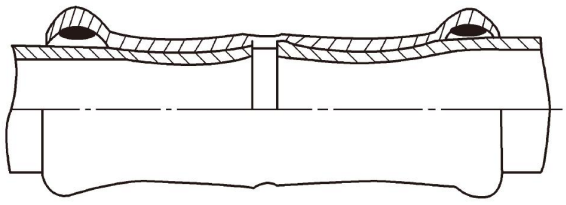
⑥ Type B for outside diameter < 150 mm only.

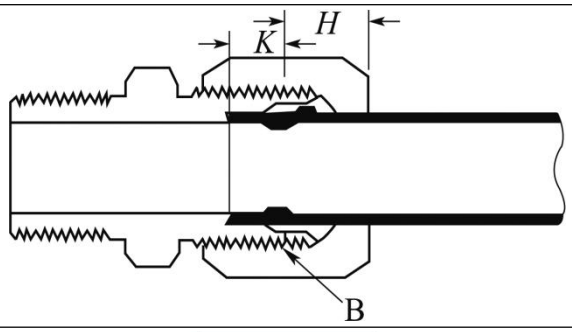
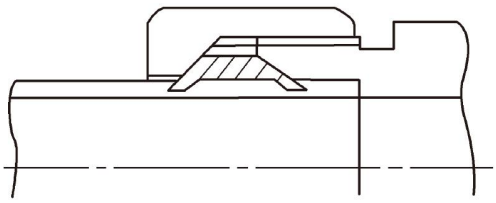
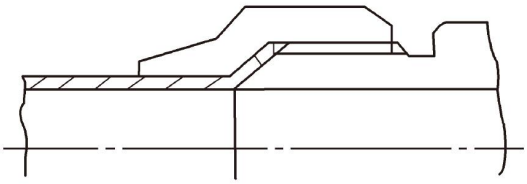
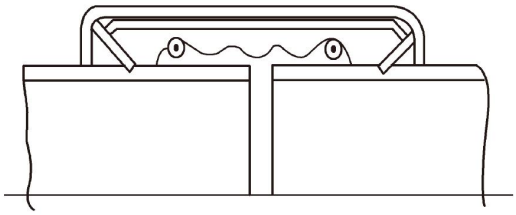
⑦ Type E for oil piping when design temperature < 150℃ and design pressure < 1.6 MPa only.

### 2.5.3 Mechanical joints

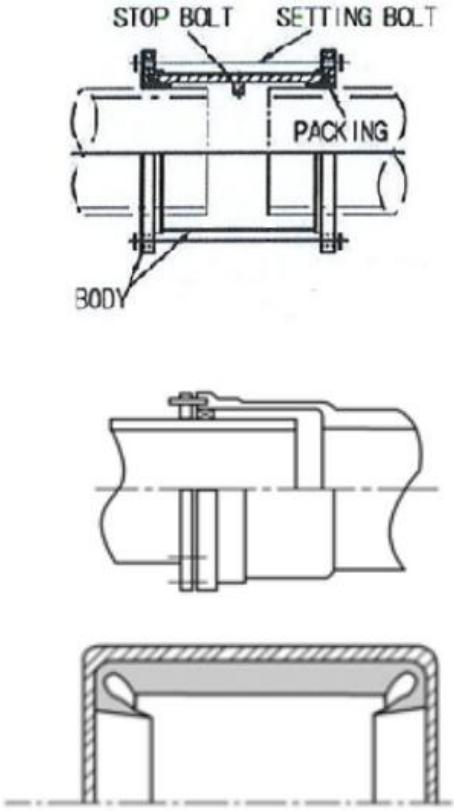
2.5.3.1 The different mechanical joints applicable to this paragraph are indicated in Table 2.5.3.1(1). The mechanical joints are to be subject to type approval based on different usage and location in accordance with the requirements of Appendix 3, Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships.

**Examples of mechanical joints** **Table 2.5.3.1(1)**

| | |
|---|---|
| Pipe unions | |
| Welded and brazed types |  |
| Compression | |
| Swage type |  |
| Press type |  |

| | |
|---|---|
| Typical Compression Type① |  |
| Bite type |  |
| Flared type |  |
| Slip-on joints | |
| Grip type |  |
| Machine grooved type |  <br>  |
| Slip type | |

① This regulation applies to any mechanical joints submitted for approval from 1 January 2020 or any renewal of existing design type approval of mechanical joints after 1 January 2020.

| | |
|---|---|
| |  |

**Application of mechanical joints** **Table 2.5.3.1(2)**

| Systems | | Kind of connections | | | | |
|---|---|---|---|---|---|---|
| | | Pipe Unions | Compress ion Couplings | Slip-on Joints | Classification of pipe system | Fire endurance test condition |
| Flammable fluids (Flash point ≤ 60°C) | | | | | | |
| 1 | Cargo oil lines① | × | × | × | dry | 30 min dry (*) |
| 2 | Crude oil washing lines① | × | × | × | dry | |
| 3 | Vent lines③ | × | × | × | dry | |
| Inert gas | | | | | | |
| 4 | Water seal effluent lines | × | × | × | wet | 30 min wet (*) |
| 5 | Scrubber effluent lines | × | × | × | wet | 30 min wet (*) |
| 6 | Main lines①② | × | × | × | dry | 30 min dry (*) |
| 7 | Distributions lines① | × | × | × | dry | 30 min dry (*) |
| Flammable fluids (Flash point > 60°C) | | | | | | |
| 8 | Cargo oil lines① | × | × | × | dry | 30 min dry (*) |

| Systems | | Kind of connections | | | | |
|---|---|---|---|---|---|---|
| | | Pipe Unions | Compress ion Couplings | Slip-on Joints | Classification of pipe system | Fire endurance test condition |
| 9 | Fuel oil lines[②③] | × | × | × | wet | 30 min wet (*) |
| 10 | Lubricating oil lines[②③] | × | × | × | wet | |
| 11 | Hydraulic oil[②③] | × | × | × | wet | |
| 12 | Thermal oil[②③] | × | × | × | wet | |
| Sea Water | | | | | | |
| 13 | Bilge lines[④] | × | × | × | dry/wet | 8 min dry + 22 min wet (*) |
| 14 | Permanent water filled fire extinguishing systems, e.g. fire main, sprinkler systems[③] | × | × | × | wet | 30 min wet (*) |
| 15 | Non-permanent water filled fire extinguishing systems, e.g. foam, drencher systems and fire main[③] | × | × | × | dry/wet | 8 min dry + 22 min wet (*) For foam systems FSS Code Chapter 6 to be observed |
| 16 | Ballast system[④] | × | × | × | wet | 30 min wet (*) |
| 17 | Cooling water system[④] | × | × | × | wet | 30 min wet (*) |
| 18 | Tank cleaning services | × | × | × | dry | Fire endurance test not required |
| 19 | Non-essential systems | × | × | × | dry dry/wet wet | Fire endurance test not required |
| Fresh Water | | | | | | |
| 20 | Cooling water system[④] | × | × | × | wet | 30 min wet (*) |
| 21 | Condensate return[④] | × | × | × | wet | 30 min wet (*) |
| 22 | Non-essential system | × | × | × | dry dry/wet wet | Fire endurance test not required |
| Sanitary/Drains/Scuppers | | | | | | |
| 23 | Deck drains (internal)[⑤] | × | × | × | dry | Fire endurance test not required |
| 24 | Sanitary drains | × | × | × | dry | Fire endurance test not required |

| Systems | | Kind of connections | | | | |
|---|---|---|---|---|---|---|
| | | Pipe Unions | Compress ion Couplings | Slip-on Joints | Classification of pipe system | Fire endurance test condition |
| 25 | Scuppers and discharge (overboard) | × | × | - | dry | Fire endurance test not required |
| Sounding/Vent | | | | | | |
| 26 | Water tanks/Dry spaces | × | × | × | dry, wet | Fire endurance test not required |
| 27 | Oil tanks (f.p.>60℃)②③ | × | × | × | dry | |
| Miscellaneous | | | | | | |
| 28 | Starting/Control air④ | × | × | - | dry | 30 min dry (*) |
| 29 | Service air (non-essential) | × | × | × | dry | Fire endurance test not required |
| 30 | Brine | × | × | × | wet | |
| 31 | CO2 system (outside protected space) | × | × | - | dry | 30 min dry (*) |
| 32 | CO2 system (inside protected space) | × | × | - | dry | Mechanical joints shall be constructed of materials with melting point above 925℃. Ref. to FSS Code Chapter 5 |
| 33 | Steam | × | × | ×⑥ | wet | Fire endurance test not required |

Notes:

× Application is allowed.

– Application is not allowed.

* Fire endurance test as specified in 1.5.5(6) of Appendix 3 of Chapter 2, PART THREE of Rules for Classification of Sea-Going Steel Ships.

-

Fire resistance capability:

If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes are to be observed:

① Fire endurance test shall be applied when mechanical joints are installed in pump rooms and open decks.

② Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.

③ Approved fire resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS Reg. II-2/9.2.3.3.2.2(10) and not used for fuel oil lines.

④ Fire endurance test shall be applied when mechanical joints are installed inside machinery spaces of category A.

General:

⑤ Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.

⑥ Slip type slip-on joints as shown in Table 2.5.3.1(1) may be used for pipes on deck with a design pressure of 10 bar or less.

⑦ If a connection has passed the “30 min dry” test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

**Application of mechanical joints depending upon the class of piping Table 2.5.3.1(3)**

| Types of joints | Classes of piping system | | |
|---|---|---|---|
| | Class I | Class II | Class III |
| Pipe unions | | | |
| Welded and brazed type | × ($D_0$≤ 60.3mm) | × ($D_0$≤60.3mm) | × |
| Compression couplings | | | |
| Swage type | × | × | × |
| Bite typ | × ($D_0$≤ 60.3mm) | × ($D_0$≤ 60.3mm) | × |
| Typical Compression Type① | × ($D_0$≤ 60.3mm) | × ($D_0$≤ 60.3mm) | × |
| Flared type | × ($D_0$≤ 60.3mm) | × ($D_0$≤ 60.3mm) | × |
| Press type | - | - | × |
| Slip-on joints | | | |
| Machine grooved type | × | × | × |
| Grip type | - | × | × |
| Slip type | - | × | × |

Notes:
× Application is allowed.
– Application is not allowed.
$D_0$ Outside diameter of the pipe.

2.5.3.2 Where appropriate, mechanical joints are to be of fire resistant type as required by Table 2.5.3.1(2). Fire endurance test is specified in 1.5.5(6), Appendix 3 of Chapter 2, PART THREE of Rules for Classification of Sea-Going Steel Ships.

2.5.3.3 Material of mechanical joints is to be compatible with the piping material and internal and external media.

2.5.3.4 Application of mechanical joints and their acceptable use for each service is indicated in Table 2.5.3.1(2); dependence upon the Class of piping and pipe dimensions is indicated in Table 2.5.3.1(3).

In particular cases, sizes in excess of those mentioned above may be accepted if in compliance with a recognized national and/or international standard.

2.5.3.5 Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.5.3.6 Mechanical joints, which in the event of damage could cause flooding or fire, are not to be used in piping sections directly connected to the ship’s side below the bulkhead deck of passenger ships (or freeboard deck of cargo ships) or tanks containing flammable fluids. The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints conforming to recognized standards are to be used.

2.5.3.7 Mechanical joints in bilge systems of machinery space and higher fire risk space (e.g. cargo pump room and vehicle space) are to be of fire resistant type. For the required fire resistant mechanical joints, see Table 2.5.3.1(2).

2.5.3.8 Mechanical joints are to be tested where applicable, to a burst pressure of 4 times the design pressure. When the design pressure exceeds 20 MPa, the burst pressure will be specially considered.

2.5.3.9 Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.5.3.10 Slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces

① This regulation applies to any mechanical joints submitted for approval from 1 January 2020 or any renewal of existing design type approval of mechanical joints after 1 January 2020.

which are not easily accessible, except that these joints may be permitted in tanks that contain the same media.
Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.
2.5.3.11 Mechanical joints are not to be used in the following cases:
(1) bilge piping through ballast tanks and fuel tanks;
(2) sea water and ballast piping (including air and overflow pipes) through cargo holds and fuel tanks;
(3) fuel and oil piping (including air and overflow pipes) through machinery spaces, cargo holds and ballast tanks.
2.5.3.12 The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

### 2.5.4 Heat treatment and non-destructive testing

2.5.4.1 The heat treatment and non-destructive testing of piping systems are to comply with the relevant requirements of CCS Rules for Materials and Welding.

## Section 6 PUMPS, VALVES AND FITTINGS

### 2.6.1 Pumps

2.6.1.1 Pumps are to be designed and manufactured according to accepted standards.
2.6.1.2 Hydraulic tests
All components of pumps subject to pressure are to be subject to hydraulic tests in workshop prior to assembly. The hydraulic test pressure is to be 1.5 times the design pressure, but need not exceed the design pressure plus 7 MPa.
For centrifugal pumps, the design pressure is to be taken as the maximum pressure head on the performance curve. For displacement pumps, the design pressure is to be taken as the relief valve setting pressure.
For steam driven pumps, the test pressure at the steam side is to be 1.5 times the steam working pressure.
2.6.1.3 Capacity tests
Pump capacities are to be checked with the pump operating at design conditions (rated speed and pressure head). For centrifugal pumps, the pump characteristic (head-capacity) design curve is to be verified to the satisfaction of the Surveyor.
Capacity tests may be waived if previous satisfactory tests have been carried out on similar pumps.
2.6.1.4 Relief valve capacity test
For positive displacement pumps with an integrated relief valve, the valve's setting and full flow capacity corresponding to the pump maximum rating is to be verified.
The operational test for relief valve capacity may be waived if previous satisfactory tests have been carried out on similar pumps.

### 2.6.2 Valves and fittings

2.6.2.1 Valves are to be designed and manufactured according to accepted standards. For other structurally new-type valves or non-standard valves, detailed drawings and information are to be submitted.
2.6.2.2 The strength of valves and fittings in piping system is to be appropriate to the strength required by the connected pipes and is to be able to work efficiently under the maximum working pressure. Valves are to be made of steel, cast iron, copper, copper alloy or other materials suitable for the intended service.
2.6.2.3 All valves are to be so constructed as to prevent the possibility of valve bonnets or glands being slackened back or loosened when the valves are operated. Screwed-on valve bonnets are not to be used for valves with nominal diameter exceeding 40 mm in Class I and Class II piping

systems, sea valves, ship-side valves and valves in flammable liquid system.
2.6.2.4 Valves on board ships are to be of such construction that the closing of which is obtained by clockwise rotation of the hand wheel, and the opening by counter-clockwise rotation.
2.6.2.5 Indicators are to be provided to show the open and closing condition of the valves, unless this can be observed in some other way; for remotely controlled valves, the remote control position is also to show the open and closing condition of the valve.
2.6.2.6 Valves and cocks are to be fitted with nameplates to indicate their purposes. The casing of non-return valves is to be permanently marked with flow direction.
2.6.2.7 The welded necks on the valve bodies are to be long enough to ensure that the valves will not deform due to welding and subsequent heat treatment of the joints.
2.6.2.8 All valves are to be subject to hydraulic tests in workshop. The hydraulic test pressure is to be 1.5 times the design pressure.

### 2.6.3 Air pipe closing devices

2.6.3.1 Where air pipes are required by 1.8.7.5 of PART TWO of the Rules to be fitted with automatic closing devices, they are to be designed, manufactured and tested in accordance with the requirements of Appendix 4 of Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships.

## Section 7 TESTS

### 2.7.1 Hydraulic tests for piping prior to installation on board

2.7.1.1 All Classes I and II pipes and their associated fittings and, all steam pipes, feed pipes, compressed air pipes and fuel oil pipes having a design pressure greater than 0.35 MPa together with their fittings are to be hydraulically tested after completion of manufacture and before insulating and coating.

2.7.1.2 The hydraulic test pressure $P_s$ is not to be less than that determined by the following formula:

$$P_s = 1.5\ p \qquad \text{MPa}$$

where: $p$ — design pressure, in MPa, see 2.1.3 of this Chapter.

2.7.1.3 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300°C, test pressure Ps is to be determined by the following formula, but need not exceed $2p$.

$$P_s = 1.5\frac{[\sigma]_{100}}{[\sigma]_t}p \qquad \text{MPa}$$

where: $p$— as defined in 2.7.1.2;
$[\sigma]_{100}$— permissible stress for 100°C, in N/mm$^2$;
$[\sigma]_t$— permissible stress for the design temperature, in N/mm$^2$.
The test pressure may be reduced to 1.5 p where it is necessary to avoid excessive stress in way of bends and T-connections. In no case is the membrane stress to exceed 90% of the yield stress at the testing temperature.
2.7.1.4 When the hydraulic test of piping is carried out on board, it may be carried out concurrently with the tightness tests required after assembly on board.
2.7.1.5 For pipes with an internal diameter less than 15 mm, the hydraulic test may be waived.
2.7.1.6 When, for technical reasons, it is not possible to carry out complete hydraulic test for all sections piping, prior to assembly on board, applications are to be submitted for approval for testing the closing lengths of piping, particularly in respect to closing seams.

### 2.7.2 Hydraulic tests for valves and fittings prior to installation on board

2.7.2.1 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be hydraulically tested in accordance with recognized standards, but the test pressure is not to be less than 1.5 times the design pressure.

Valves, cocks and distance pieces intended to be fitted on the ship side below the load waterline are to be tested by hydraulic pressure not less than 0.5 MPa.

### 2.7.3 Testing after assembly on board

2.7.3.1 All piping systems are to be checked for leakage under working conditions.

2.7.3.2 Fuel (oil or gas) piping, heating coils in tanks, bilge pipes in way of double bottom tanks or deep tanks and hydraulic piping are to be tested by hydraulic pressure in accordance with Table 2.7.3.2.

**Hydraulic tests after assembly on board** **Table 2.7.3.2**

| Piping system | Test pressure |
|---|---|
| Fuel (oil or gas) piping | 1.5 times design pressure, but not less than 0.4 MPa |
| Heating coils in tanks | |
| Bilge pipes in way of double bottom tanks or deep tanks | Not less than test pressure of the tank |
| Hydraulic piping | 1.25 times design pressure, but no need to exceed design pressure plus 7 MPa |

2.7.3.3 Where Classes I and II pipes are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 2.7.1.1 to 2.7.1.4 after welding. During installation and before the hydraulic test is carried out, the pipe lengths may be insulated, except in way of the joints.

2.7.3.4 The hydraulic test required in 2.7.3.3 of this Section may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

## Section 8 ARRANGEMENT

### 2.8.1 Piping arrangement

2.8.1.1 All pipes are to be properly secured, and provision is to be made to avoid excessive stresses caused by thermal expansion in pipes or due to deflection of ship structure.

2.8.1.2 Penetration pieces or steel pads are to be provided for pipes passing through watertight or gastight structures. If pipes are fixed on watertight bulkhead by bolts, bolt holes are not to pass through bulkhead.

For pipes pass through deck or bulkhead with fire division, their arrangement is not to damage fire division of deck or bulkhead.

2.8.1.3 The pipe piercing the collision bulkhead below the freeboard deck (bulkhead deck for passenger ships) is to be fitted with a remotely controlled valve capable of being operated from above the freeboard deck (bulkhead deck for passenger ships)The valve is to be normally closed. If the remote control system should fail during operation of the valve, the valve is to close automatically or be capable of being closed manually from a position above the freeboard deck (bulkhead deck for passenger ships).

The above-mentioned valve are to be fitted on the forward or the after side of the collision bulkhead provided that the space in which they are located is not a cargo space.

All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

2.8.1.4 The collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank. If the forepeak is divided to hold two different

kinds of liquids, the collision bulkhead of each compartment may be allowed to be pierced below the bulkhead deck for passenger ships by one pipe.
2.8.1.5 For ships required for damage stability, the arrangement is to ensure that the continuing flooding will not extend to the compartments other than those with assumption of flooding , provided the piping system is fitted in the assumed flooding compartments.
2.8.1.6 Fresh water pipes are not to be led through oil tanks, nor oil pipes through fresh water tanks. Where it is impracticable to do so, the pipes are to be led inside an oil-tight pipe tunnel.

**2.8.2 Separation of tanks**
2.8.2.1 Where the following tanks are adjacent to each other, they are to be separated by cofferdams:
(1) lubricating oil tanks and fresh water tanks;
(2) boiler feed water tanks and fuel oil tanks;
(3) fresh water tanks and fuel oil tanks;
(4) boiler feed water tanks and lubricating oil tanks.
2.8.2.2 Where the fuel oil tank is directly adjacent to lubricating oil tank, the welding of the adjacent bulkhead is to be of full penetration type.

**2.8.3 Corrosion protection**
2.8.3.1 Steel pipes are to be protected against corrosion, and protective coatings are to be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

**2.8.4 Fire protection**
2.8.4.1 Air, overflow and sounding pipes for fuel oil tanks are not to be led through living quarters. Where this is not practicable, no detachable pipe joint is permissible in these spaces.
2.8.4.2 All steam, oil and water pipes as well as oil and other liquid tanks are not to be placed above or behind the switchboard. If this is not practicable, suitable protective means are to be provided.
In addition, oil pipes and oil tanks are not to be directly placed above the boilers, uptakes, steam pipes, exhaust gas pipes and silencers. If this is impracticable, effective means are to be made to prevent oil dropping onto the hot surfaces of the above-mentioned pipes or equipment.

**2.8.5 Protection**
2.8.5.1 Seawater pipes in cargo holds for dry cargoes, including cargo spaces of container ships, ro-ro ships, are to be protected from impact of cargo where they are liable to be damaged.
2.8.5.2 All pipes, fittings, pumps, filters and other equipment of piping systems are to be provided with drain valves or cocks where necessary.
2.8.5.3 The pipes which may be subject to a pressure greater than the design value are to be fitted with relief valves at the delivery side of pumps. The discharge from relief valves fitted in oil pipelines is to be led to the suction side of pumps or tanks. Heaters and air compressor coolers are also to be fitted with relief valves. The releasing pressure of relief valves is, in general, not to be greater than the design pressure of pipelines.
2.8.5.4 Where pressure-reducing valves are fitted in the pressure piping, a relief valve and a pressure gauge are to be fitted behind the pressure-reducing valve and a by-pass pipe fitted with a screw-down valve is to be provided. Or, at least an additional spare pressure reducing valve for replacement at any time is to be provided. The provision of pressure-reducing valves in the gas supply piping of the control system and relevant requirements are given in 2.2.2.2, PART SEVEN of the Rules.

**2.8.6 Insulation**
2.8.6.1 The insulation lagged on the machinery surfaces with a temperature over 220℃ is to comply with the provisions in 1.3.6.3 of this PART. The insulation in way of dismountable joints and valves is to be easily renewed.
2.8.6.2 Pipes passing through refrigerated spaces (including fish rooms), excluding those intended to serve such spaces, are to be well insulated to prevent freezing and from the steel structure.

2.8.6.3 Where the pipes pass through chambers intended for temperatures of 0℃ or below, they are in general to be insulated from the steel structure of these chambers.

### 2.8.7 Compensation for expansion

2.8.7.1 Suitable provision for compensation is to be made for all pipes subject to expansion, contraction or other strain, such as bends, loops, or expansion joints as required.

2.8.7.2 The adjoining pipes are to be suitably aligned and anchored. Where necessary, expansion pieces of bellows type are to be protected against mechanical damage.

2.8.7.3 In general, slip type expansion joints are only used for pipes in spaces accessible to operators for inspection during normal navigation. Slip type expansion joints are not to be used for pipes in spaces such as dry cargo tank and deep tank which are not easy to inspect. Slip type expansion joints may be used for pipes in tanks carrying the same liquid as that in the pipes.

Slip type expansion joints are not to be used in the systems listed below:

(1) class I Piping system;

(2) oil (such as fuel oil, lubricating oil, hydraulic oil, thermal oil) pipes of Class II piping system;

(3) steering gear hydraulic system;

(4) starting air and control air system;

(5) boiler feed water system;

(6) fixed gas fire extinguishing system;

(7) bilge pipelines located in cargo hold, deep tanks and double bottom tanks;

(8) cargo oil lines located in pipe duct keels;

(9) oil pipes, such as fuel oil, lubricating oil, hydraulic oil and thermal oil, of Class III systems located in machinery spaces of category A, accommodation spaces or non-mechanically ventilated pipe duct keels;

(10) pipes passing through other tanks;

(11) exhaust system.

For detailed requirements to slip type expansion joints, see relevant provisions in 2.5.3 of Section 5 of this Chapter.

### 2.8.8 Installation of valves and fittings

2.8.8.1 Valves, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed into but not penetrating through the pads welded on the plating. Alternatively, the studs or the bulkhead piece may be welded to the plating.

2.8.8.2 The valves and fittings fitted in engine rooms, boiler rooms, pump rooms and shaft tunnels are to be easily accessible for operation. Where the valves and fittings are situated under the floor plate not easily accessible for operation, they are to be provided with extended operating rods or tools for operation. Furthermore, holes are to be cut in the floor plate under which the valves or fittings are located and to be provided with covers.

2.8.8.3 Where relief valves are fitted in sea water systems, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

2.8.8.4 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. Opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

Sea valves, ship-side valves and valves on collision bulkhead are to be permanently arranged for local manual operation.

### 2.8.9 Installation of ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.8.9.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel sea chests attached to the shell plating. The installation of the valves or cocks is to comply with the following requirements in (1) or (2):

(1) The valves or cocks are to be secured by means of studs screwed into but not penetrating through the pads welded on the shell plating or sea chests.

(2) The valves or cocks may be secured to the distance piece welded on the shell plating or sea

chests. The wall thickness of the distance piece is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the distance piece. The distance piece is to be adequately strengthened as to ensure its rigidity.

2.8.9.2 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-off valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.

2.8.9.3 Blow-off valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut.

2.8.9.4 It is to be avoided to locate the overboard discharges in way of the areas where the lifeboats and accommodation ladders are lowered. Where this is not practicable, suitable means are to be provided to prevent any discharge of water into the lifeboats or onto the accommodation ladders.

2.8.9.5 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. The operating position of hand wheel or manual operating device of main sea inlet valve is to be situated not less than 450 mm above the lower platform.

If an inlet or outlet pipeline passes through wing tank, the above-mentioned ship-side valve may be installed on inner bulkhead of wing tank. The wall thickness of pipes between inner bulkhead and shell plate of wing tank is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the pipes.

2.8.9.6 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and sea chests. The direction of grating bars is to be in line with the length of the ship. The net area through the gratings is not to be less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air.

2.8.9.7 Ship-side valves and fittings as well as sea chests, if made of steel, are to be suitably protected against wastage.

2.8.9.8 Sea chests are to be so arranged as to avoid the formation of air pocket. Where a vent pipe is fitted on the top of the sea chest, a screw-down valve is to be fitted at the root of the vent pipe. The open end of the vent pipe is to be extended to a position above the bulkhead deck or to be led overboard in the vicinity of the bulkhead deck and a ship-side screw-down valve is to be fitted.

# CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS

## Section 1 GENERAL PROVISIONS

### 3.1.1 Application

3.1.1.1 The requirements of this Chapter apply to piping and ventilating systems on ships except where otherwise stated.

### 3.1.2 Materials

3.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

3.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see Section 4 of Chapter 2 of this PART.

### 3.1.3 Plans and documents

3.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

## Section 2 DRAINAGE OF COMPARTMENTS, OTHER THAN MACHINERY SPACES

### 3.2.1 General requirements

3.2.1.1 All ships are to be provided with efficient bilge pumping systems capable of pumping from and draining any watertight compartment, other than a space permanently appropriated for the carriage of fresh water, water ballast, oil fuel or liquid cargo, and any other space where efficient means of pumping are available under all practical conditions. For particular compartments, if the survival capability and the safety of the ship are not impaired by flooding of the compartments, bilge pumping arrangements may be dispensed with.

Efficient means are to be provided for draining water from insulated holds. For their particular requirements, see relevant provisions specified in Chapter 3 of PART FIVE of the Rules.

3.2.1.2 The suctions and means for drainage are to be so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.2.1.3 In passenger ships, the bilge pumping plant is to be capable of draining any one watertight compartment which is neither a permanent oil compartment nor a permanent water compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

**Bilge suction arrangements in cargo holds** **Table 3.2.2.1**

| Cargo holds condition | | Suction arrangement in each cargo hold |
|---|---|---|
| Without double bottom | Bottom shell slopping down to the center line ≥ 5° | One near center line at after end |
| | Bottom shell slopping down to the center line < 5° | One on each side at after end |
| With double bottom | Inner bottom plating extending to ship's side and forming bilges at the wings | One on each side |

| Cargo holds condition | | Suction arrangement in each cargo hold |
|---|---|---|
| | Inner bottom slopping down to the center line | One near center line |
| | Inner bottom plating extending to ship's side and not forming bilge | One bilge well with suction on each side |
| In ships having only one hold, and the length of the hold exceeds 35 m | | Fitted in forward half-length and after half-length of the hold |
| In narrow holds at the ends of ships | | One near center line |

### 3.2.2 Cargo holds

3.2.2.1 The bilge suctions in cargo holds are to be arranged in accordance with Table 3.2.2.1.

3.2.2.2 Enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship

Drainage arrangement of enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship may discharge in the form of gravity drainage by means of scupper according to the following requirements:

(1) Where the freeboard to the bulkhead deck or the freeboard deck, respectively, is such that the deck edge is immersed when the ship heels more than 5°, the drainage is to be by means of a sufficient number of scuppers of suitable size discharging directly overboard.

The arrangement of such scupper pipes is to be in accordance with the requirements in 2.11 of Chapter 2, PART THREE of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages.

(2) Where the freeboard is such that the edge of the bulkhead deck or the edge of the freeboard deck, respectively, is immersed when the ship heels 5° or less, the drainage of the enclosed cargo spaces on the bulkhead deck or on the freeboard deck, respectively, is to be led to a suitable space, or spaces, of adequate capacity, having a high water level alarm and provided with suitable arrangements for discharge overboard.

(3) Scuppers are to be provided at both port and starboard. The number and disposition of the scuppers are such as to prevent unreasonable accumulation of free water. Grills are to be provided at the open end of the scupper and the scuppers are not to be less than 100 mm in diameter.

(4) Where the enclosed cargo space is protected by a fixed pressure water-spraying fire-extinguishing system, the pumping arrangements are to take into account the requirements for any fixed pressure water-spraying fire-extinguishing system.

(5) Where the enclosed cargo space is protected by a carbon dioxide free-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

(6) Water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present.

### 3.2.3 Holds and deep tanks for alternative carriage of liquid or dry cargo

3.2.3.1 Where the inner bottom is slopping down to the centre line with an angle of not less than 5°, one centre suction only will be accepted and the wing suctions may be omitted.

3.2.3.2 In holds and deep tanks for alternative carriage of liquid or dry cargo, the liquid cargo and water ballast filling and suction pipes are to be provided with blanking flanges or other equivalent means, also the bilge suction pipes are to be provided with blanking flanges in way of the bulkheads, so as to isolate the filling and suction pipes when the hold or tank is being used for the carriage of dry cargo, and to isolate the bilge suction pipes when the hold or tank is being used for the carriage of liquid cargo or water ballast.

### 3.2.4 Fore peaks, after peaks and cofferdams

3.2.4.1 Where the peaks are used as dry compartments, the drainage of both peaks is to be effected either by a power pump branch bilge suction or a hand pump suction. In the latter case, the suction lift is in no case to exceed 7 m.

3.2.4.2 Suitable drainage arrangements are to be provided in cofferdams.

### 3.2.5 Spaces above fore peaks, after peaks and machinery spaces

3.2.5.1 The chain locker and the watertight compartments above the fore peak tank are to be drained by hand pump or power pump bilge suctions. Other effective means of drainage are also acceptable.

3.2.5.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be drained either by hand pump or power pump bilge suctions. Such compartments may also be drained by scuppers of not less than 38 mm bore, discharging to the shaft tunnels (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks or shut-off valves situated in well lighted and easily visible positions.

### 3.2.6 Shaft tunnel and pipe tunnel

3.2.6.1 The shaft or pipe tunnel is, in general, to be drained by a branch bilge suction at the after end of the tunnel. Where water might accumulate at the forward end of the tunnel or the length of the tunnel is more than 35 m, additional bilge suction is required.

## Section 3 BILGE DRAINAGE OF MACHINERY SPACES

### 3.3.1 General requirements

3.3.1.1 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be branch bilge suction, and the other is to be direct bilge suction.

3.3.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

### 3.3.2 Bilge suction arrangements in machinery spaces

3.3.2.1 The bilge suctions in machinery spaces are to be arranged in accordance with Table 3.3.2.1.

For cargo ships for coastal service and services lower than coastal service or ships of less than 500 gross tonnage, the number of direct suctions in the Table may be changed to 1.

For ships of less than 500 gross tonnage, the number of branch suctions in the Table may be changed to 2.

For ships of less than 100 gross tonnage, the number of branch suctions in the Table may be changed to 1.

3.3.2.2 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crank-pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

3.3.2.3 In ships propelled by electrical machinery, in addition to the branch bilge suctions and direct bilge suctions arranged appropriate to the conditions of machinery space, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

3.3.2.4 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided, there is to be at least one suction on each side of the space.

**Bilge suction arrangements in machinery spaces** **Table 3.3.2.1**

| Condition of machinery spaces | | Branch bilge suction | Direct bilge suction |
|---|---|---|---|
| Main engine room with single bottom | Bottom shell slopping down to the center line ≥ 5° | One near center line | One near center |
| | Bottom shell slopping down to the center line < 5° and all passenger ships | One near center line and one on each side | One near center |
| Main engine room with double bottom | Inner bottom extends the full length of the machinery space and forms bilges at the wings | One on each side | One on each side |
| | Inner bottom extends the full length and breadth of the machinery space | One bilge well with one suction on each side | One bilge well with one suction on each side |
| Ships with propelling machinery aft | | One on each side at the fore end and one at central longitudinal plane at aft end | One on each side at the fore end of engine room |

| Condition of machinery spaces | Branch bilge suction | Direct bilge suction |
|---|---|---|
| Boiler room or auxiliary engine room separated from the main engine room by watertight bulkheads; separate motor room of electrically propelled ships | Same as for cargo holds | At least one for each watertight compartment |

### 3.3.3 Emergency bilge suctions of machinery spaces

3.3.3.1 In addition to the bilge suctions required in 3.3.2.1 to 3.3.2.4 of this Section, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to a main cooling water pump and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is 450 mm above the bottom platform.

3.3.3.2 In ships with steam propelling machinery, the emergency suction is to have a diameter of at least 2/3 that of the main circulating pump suction. In other ships, the diameter of suction is not to be less than the diameter of the pump suction.

3.3.3.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest power pump which is not a bilge pump. This pump is to have a capacity not less than that required for a bilge pump, and the bilge suction is at least to be the same size as that of the pump suction branch.

Where the pump to which the emergency bilge suction is connected is of the self-priming type, the direct bilge suction on the same side of the ship may be omitted, except in passenger ships.

3.3.3.4 Emergency bilge suction valves are to be provided with permanent nameplates clearly indicating their purpose.

3.3.3.5 For the following ships, the emergency bilge suction is not required to be provided in machinery spaces.

(1) cargo ships of less than 500 gross tonnage;

(2) passenger ships of less than 100 gross tonnage;

(3) passenger ships of less than 500 gross tonnage in sheltered water service.

## Section 4 BILGE PUMPS AND BILGE PIPING

### 3.4.1 Number of bilge pumps

3.4.1.1 The number of power bilge pumps for each ship is to comply with the requirements of Table 3.4.1.1. However, the following ships may comply with the following requirements:

For passenger ships of less than 100 gross tonnage and carrying no more than 100 passengers, if the sailing time is no more than 4 hours, two independent power bilge pumps may be provided;

For ships of less than 100 gross tonnage, bilge pump may only be provided with a pump driven by engine and a manual pump.

**Number of power bilge pumps** **Table 3.4.1.1**

| Ship type, navigation area and parameters | | | Independent power pump | Power pump driven by main engine or independent power pump |
|---|---|---|---|---|
| Passenger ship | Passenger ships in greater coastal service or services upper than greater coast; Passenger ships carrying more than 500 passengers in coastal service; | Bilge pump numeral ≥ 30 | 3 | 1 |
| | | Bilge pump numeral < 30 | 2 | 1 |
| | Passenger ships other than those listed above | | 2 | 1 |
| Ships other than passenger ship | | Ship's length > 91.5m | 2 | – |
| | | Ship's length ≤ 91.5m | 1 | 1 |

3.4.1.2 Each bilge pump prescribed in 3.4.1.1 of this Section may be substituted by a pumping unit consisting of several pumps. The total capacity of each pumping unit is not to be less than the capacity of a bilge pump specified in 3.4.2.4 of this Section.

3.4.1.3 Independent power sanitary, ballast and general service pumps may be accepted as independent power bilge pumps, provided they are of the required capacity of the self-priming type or with the self-priming arrangement and connected to the bilge main.

3.4.1.4 For ships other than passenger ships, an ejector with an adequate pressure of water supply from a sea water pump and connected to the bilge piping may be accepted as an independent power bilge pump.

3.4.1.5 For passenger ships, the bilge pump numeral $C$ is to be calculated as follows:

when $P_1$ is greater than $P$: $C = \dfrac{72(M + 2P_1)}{V + P_1 - P}$

in other cases: $C = \dfrac{72(M + 2P)}{V}$

where:

$M$ — the volume of the machinery space, in $m^3$, as defined in 1.2.1 of Chapter 2-1, PART FOUR of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, that is below the bulkhead deck; with the addition thereto of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and the machinery space or abaft the machinery space;

$V$— the whole volume of the ship below the bulkhead deck, in $m^3$;

$P$— the whole volume of the passenger and crew spaces below the bulkhead deck, in $m^3$, which are provided for the accommodation and use of passengers and crew, excluding baggage, store, provision and mail rooms;

$$P_1 = KN$$

where:

$N$ — the number of passengers for which the ship is to be certified; and

$K = 0.056L$

where:

$L$ — the length of the ship, in m, as defined in 1.2.1 of Chapter 2-1, PART FOUR of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages.

However, where the value of $KN$ is greater than the sum of $P$ and the whole volume of the actual passenger spaces above the bulkhead deck, the figure to be taken as $P_1$ is that sum or two-thirds $KN$, whichever is the greater.

### 3.4.2 Type and capacity of bilge pumps

3.4.2.1 All power bilge pumps are to be of the self-priming type, or with the self-priming arrangements.

3.4.2.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type, or with self-priming arrangements.

3.4.2.3 Each power bilge pump is to be capable of giving a speed of water through the required main bilge pipe of not less than 2 m per second.

3.4.2.4 The capacity of each bilge pump ($Q$) is not to be less than the value calculated by the following formula:

$$Q = 5.66\, d_1^2 \times 10^{-3} \quad m^3/h$$

where: $d_1$ — internal diameter of bilge main, obtained from the formula in 3.4.3.1 of this Section, in mm.

3.4.2.5 In ships other than passenger ships, where one bilge pump is of slightly less than the rule capacity, the deficiency may be made good by an excess capacity of the other pumps. In general, this deficiency is to be limited to 30%.

### 3.4.3 Bilge pipe systems

3.4.3.1 The internal diameter $d_1$ of the bilge main is to be calculated according the following formula. However, the actual internal diameter of the bilge main may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_1 = 25 + 1.68\sqrt{L(B + D)} \quad mm$$

where: $L$ — length of ship, in m (measured between perpendiculars taken at the extremities of the deepest subdivision load line).
Where the engine room bilge pumps are fitted primarily for serving the engine room and they do not serve cargo space bilges, $L$ may be reduced by the combined length of the cargo tanks or cargo holds. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines;

$B$ — breadth of ship, in m (the extreme width from outside of frame to outside of frame at or below the deepest subdivision load line).

$D$ — molded depth of ship to bulkhead deck, in m.
When the bilge of enclosed cargo spaces situated on the bulkhead deck or freeboard deck is drained by means of bilge system, $D$ is to be selected according to following requirements:

(1) when the enclosed cargo space extends for the full length of the ship, $D$ is to be measured to the next deck above the bulkhead deck;

(2) where the enclosed cargo spaces cover a lesser length, $D$ is to be taken as the molded depth to the bulkhead deck plus $lh/L$, where $l$ and $h$ are the aggregate length and height respectively of the enclosed cargo spaces.

3.4.3.2 In no case is the internal diameter of the bilge main to be less than that required for the largest branch bilge line.

3.4.3.3 The internal diameter $d_2$ of branch bilge suction pipes fitted in cargo and machinery spaces is not to be less than the value determined by the following formula, but the actual internal diameter of branch bilge suction pipes may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_2 = 25 + 2.15\sqrt{l(B+D)} \quad \text{mm}$$

where: $l$ — length of compartment, in m;
$B$— breadth of ship, in m;
$D$— molded depth of ship to bulkhead deck, in m.

3.4.3.4 In general, no branch bilge suction pipe is to be less than 50 mm bore.
For ships of less than and up to 25 m in length, the branch bilge suction pipe is, in general, not to be less than 40 mm bore.

3.4.3.5 In no case is the internal diameter of the direct bilge suction to be less than that required for the main bilge line.

3.4.3.6 The branch bilge suction pipe to the tunnel well is, in general, not to be less than 65 mm bore.
For ships of less than and up to 60 m in length, the branch bilge suction pipe to the tunnel well is, in general, not to be less than 50 mm bore.

3.4.3.7 The section area of each branch pipe connecting the bilge main to a distribution chest is not to be less than the sum of the areas required for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

### 3.4.4 Bilge pumps and pipe connections

3.4.4.1 The connections at the bilge pumps are to be such that at least one of the pumps may continue in operation when the other pumps are being opened up for overhaul.

3.4.4.2 The arrangements of pump and pipelines are such that the working of any of the pumps so connected is unaffected by the other pumps being in operation at the same time.

3.4.4.3 All bilge suction pipes are to be independent of other piping up to the bilge pump suction valve chest.

### 3.4.5 Non-return arrangements

3.4.5.1 For the purpose of preventing the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks, screw-down non-return valves are to be provided in the following fittings:
(1) bilge valve distribution chests;
(2) bilge suction hose connection, whether fitted direct to the bilge pump or on the main bilge line;
(3) direct bilge suctions;

(4) bilge pump connections to main bilge line.

### 3.4.6 Blanking arrangements

3.4.6.1 In the case of deep tanks and cargo holds which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank or hold is being used for the carriage of dry cargo, and for blank flanging the bilge suction pipes when the tank or hold is being used for the carriage of water ballast.
For arrangement when oil fuel or cargo oil (having a flash point above 60℃) is carried in deep tanks, see 4.2.9.1 of this PART.

### 3.4.7 Bilge pipes in way of deep tanks and double bottom tanks

3.4.7.1 In way of deep tanks, bilge pipes are preferably to be led through pipe tunnels but, where this is not done, the pipes are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART, with welded joints or other reliable joints. The number of joints is to be kept to a minimum.
3.4.7.2 Expansion bends, not glands, are to be fitted to these pipes within the deep tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the approved type.
3.4.7.3 Bilge suction pipes are not to be led through double bottom tanks as far as practicable. Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART.
3.4.7.4 Expansion bends, not glands, are to be fitted to these pipes within the double bottom tanks.
3.4.7.5 The pipes are to be tested after installation, to a pressure not less than that required for the deep or double bottom tanks through which they pass.

### 3.4.8 Bilge fittings

3.4.8.1 Where the inner bottom plating in machinery spaces or cargo holds extends to the ship's side and does not form bilges, the bilge suctions are to be arranged in bilge wells. The bilge wells are to be formed of steel plates and are not to be less than 0.15 $m^3$ in capacity.
For ships of less than 500 gross tonnage, the capacity of bilge wells in machinery spaces or cargo holds may be slightly reduced but is not to be less than 0.10$m^3$.
3.4.8.2 Each branch bilge suction and each direct bilge suction in machinery spaces and tunnels (excluding emergency suctions) are to be led from easily accessible mud boxes fitted with straight tail pipes to the wells or bilges. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.
For ships of less than 100 gross tonnage, strum boxes may be fitted instead to the ends of bilge suctions in machinery spaces.
3.4.8.3 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The strum boxes are to be so constructed that they can be easily removed and replaced for cleaning.
3.4.8.4 Bilge valves, cocks and mud boxes are as far as possible to be fitted at, or above, the machinery space and tunnel platforms. Where they are situated just below the platform, provided readily removable traps or covers are to be fitted, and nameplates are to be fitted to indicate the presence of these fittings.

### 3.4.9 Miscellaneous

3.4.9.1 The design, construction and arrangement of sludge tanks and standard discharge connections are to comply with the provisions of relevant domestic regulations.
3.4.9.2 Bilge piping systems are to be so arranged as to meet the relevant requirements for the prevention of pollution from ships.

# Section 5 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE FOR PASSENGER SHIPS

### 3.5.1 Arrangement of bilge pumps and bilge main

3.5.1.1 In passenger ships the required power bilge pumps are to be placed, if practicable, in separate watertight compartments. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

3.5.1.2 In passenger ships of 91.5 m or more in length, or having a bilge pump numeral of 30 or more, the arrangements are to be such that at least one of the power bilge pumps will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:

(1) one of the pumps is a reliable emergency pump of a submersible type having its source of power situated above the bulkhead deck;

(2) the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required to withstand, at least one pump in an undamaged compartment will be available.

3.5.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than $B/5$ ($B$ being the breadth of ship), measured at right angles to the centreline at the level of the deepest subdivision load line.

3.5.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $B/5$ line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the $B/5$ line.

### 3.5.2 Arrangement of bilge pipes

3.5.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $B/5$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5.2.2 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be in positions which are accessible at all times under ordinary circumstances. They are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. In addition, damage to a pump or its pipe connecting to the bilge main situated outboard of $B/5$ line is not to put the bilge system out of action. If there is only one system of pipes common to all the pumps, the necessary cocks or valves for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system, and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case only the cocks and valves necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

3.5.2.3 All cocks and valves mentioned in 3.5.2.2 of this Chapter which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

# Section 6 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE

### 3.6.1 Additional requirements for bilge drainage for oil tankers

3.6.1.1 For the additional requirements for bilge drainage for oil tankers, see relevant provisions of Section 3, Chapter 5 of this PART.

### 3.6.2 Additional requirements for bilge drainage for spaces using fixed pressure

**water-spraying fire-extinguishing systems**[①]

3.6.2.1 Pumping and drainage facilities are to be provided in spaces using fixed pressure water-spraying fire-extinguishing systems for draining large quantities of water accumulation on the deck or tank top on consequence of the operation of the fixed pressure water-spraying system, and following requirements are to be complied with.

(1) For passenger ships:

① In the spaces above the bulkhead deck, scuppers complying with relevant requirements of MSC.1/Circ.1320 are to be fitted so as to ensure that such water is rapidly discharged overboard.

Discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements in 2.11 of Chapter 2, PART THREE of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages, are to be kept open while the ships are at sea.

② In the spaces below the bulkhead deck, pumping and drainage facilities complying with relevant requirements of MSC.1/Circ.1320 may be required to be provided additional to the requirements of Section 2 to Section 5 of this Chapter. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

(2) For cargo ships:

The drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces and comply with relevant requirements of MSC.1/Circ.1320. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account in its approval of the stability information. Such information is to be included in the stability information supplied to the master as required.

3.6.2.2 On all ships, for closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means are to be provided to prevent the blockage of drainage arrangements and relevant requirements of MSC.1/Circ.1320 are to be complied with.

### 3.6.3 Additional requirements for bilge drainage for unattended other machinery spaces

3.6.3.1 Bilge level alarms are to be provided for unattended other machinery spaces below waterline (e.g. athwartship thruster space, emergency fire pump space, etc.).

## Section 7 DRAINAGE ARRANGEMENTS AND BALLAST PIPING FOR NON-SELF-PROPELLED SHIPS

### 3.7.1 General requirements

3.7.1.1 Non-self-propelled ships are to be provided with means for drainage of all watertight compartments which give contribution to the vessel's buoyancy and floatability (except for compartments permanently used to carry liquid).

3.7.1.2 This Section is the additional requirements to drainage arrangements and ballast piping for non-self-propelled ships. With the exemption specified in the following, the rules and principles for drainage of ship with propulsion machinery are to be referred to.

### 3.7.2 Pierhead pontoon and non-self-propelled ships without auxiliary power

3.7.2.1 For pierhead pontoon and non-self-propelled ships without auxiliary power, at least two portable hand pumps are to be fitted to permit the efficient drainage of each compartment. Suitable access hatches for the pumping equipment are to be provided for each compartment.

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① Refer to MSC.1/Circ.1320: Guidelines for the Drainage of Fire-fighting Water from Closed Vehicle and Ro-Ro Spaces and Special Category Spaces of Passenger and Cargo Ships.

3.7.2.2 The internal diameter $d$ of the hand pump suction is not to be less than the value determined by the following formula:

$$d = 0.01T + 50 \quad \text{mm}$$

where: $T$ — tonnage under upper deck, in t.

Where the ship is subdivided into small watertight compartments, 50 mm bore suction will be accepted. The internal diameter of the water cylinder of piston pumps is not to be less than twice the required diameter of the suction.

**3.7.3 Manned non-self-propelled ships with auxiliary power**

3.7.3.1 In non-self-propelled ships with auxiliary power, permanently installed bilge system with power bilge pumps are to be provided for dealing with the drainage of tanks and principal compartments.

3.7.3.2 Manned ships with auxiliary power are to be equipped with two power driven bilge pumps.

3.7.3.3 Manned ships with auxiliary power for greater coastal service or services lower than greater coast may have one power driven bilge pump, but in this case, the bilge pump is not to serve as fire pump.

3.7.3.4 All compartments required to be equipped with bilge drainage arrangements are to have branch bilge suction connected with bilge system.

3.7.3.5 In addition to branch bilge suction, a direct bilge suction to bilge pump is to be provided for the engine room.

3.7.3.6 Dry compartments in fore and aft peak may be drained by hand pumps.

3.7.3.7 Rooms situated on deck may be drained directly overboard.

**3.7.4 Unmanned non-self-propelled ships with auxiliary power**

3.7.4.1 Unmanned ships with auxiliary power are to be provided with a power driven bilge pump.

3.7.4.2 Any engine room or pump room is to have bilge suctions to power bilge pump.

3.7.4.3 Other compartments may be drained by portable pumps. Suitable access hatches for the pumping equipment are to be provided for each compartment.

**3.7.5 Ballast system of non-self-propelled ships**

3.7.5.1 For non-self-propelled ships fitted with ballast tank, each ballast tank is to be provided with ballast system connected by pipes.

3.7.5.2 Pierhead pontoon and non-self-propelled ships without auxiliary power may use a portable pump as ballast pump.

3.7.5.3 Non-self-propelled ships with auxiliary power are to be provided with at least one power driven ballast pump.

# Section 8 BALLAST AND SCUPPER SYSTEMS

**3.8.1 Ballast piping**

3.8.1.1 The arrangement of ballast piping and the number of suctions are to be such that any ballast tank can be filled or emptied under normal service conditions, whether the ship is upright or listed.

3.8.1.2 Where the ballast tanks exceed 35 m in length, they are normally to be fitted with bilge suctions at their forward and aft ends.

3.8.1.3 The arrangement of ballast piping is to be such as to prevent the possibility of water passing from the sea or from ballast tanks into dry cargo and machinery spaces or other dry compartments.

3.8.1.4 Ballast water pipes are not to pass through drinking water, boiler feed water or lubricating oil tanks. Where it is unavoidable, the wall thickness of ballast pipes in drinking water, feed water or lubricating oil tanks is to comply with the provisions of column 5 in Table 2.2.2.6(1) of this PART and welded joints are to be adopted. Ballast water pipes passing through a pipe tunnel may also be an option.

3.8.1.5 The ballast piping is not to be in connection with the bilge pipes from dry cargo and

machinery spaces, nor with the pipes from oil tanks. However, this requirement need not be applied to the pipes located between distribution boxes and pump suctions or between pumps and overboard discharges, nor to the pipes described in 3.8.1.6 below.
3.8.1.6 Where the compartments (including deep tanks) are used for alternative carriage of dry cargo or oil or ballast water, provision is to be made for isolating or blank flanging the ballast lines. This requirement is also applicable to the drinking water tanks which may be used as ballast tanks, so as to avoid the interconnection of the two systems. The arrangement for the discharge of oily ballast water is to be in accordance with the relevant requirements for the prevention of pollution from ships.
3.8.1.7 Alternate loading of fuel oil and ballast water is to comply with the relevant requirements of 4.2.8, Chapter 4 of this PART.
3.8.1.8 For the requirements of ballast system in oil tankers, see the relevant provisions in Section 3, Chapter 5 of this PART.

### 3.8.2 Scuppers and sanitary discharges
3.8.2.1 For the requirements of scuppers and sanitary discharges, see the requirements in 2.11 of Chapter 2, PART THREE of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages.
3.8.2.2 The installation of all suction and discharge valves or side standpipes on scuppers and sanitary discharges that are secured direct to the shell plating of the ship is to be in compliance with the relevant requirements of 2.8.9.2 of this PART.

## Section 9 REMOTELY CONTROLLED BILGE AND BALLAST SYSTEMS

### 3.9.1 Arrangement
3.9.1.1 If a main bilge line outside engine room is provided, its arrangement is to satisfy either of the following requirements:
(1) If there is only one main bilge line and a pipe tunnel is provided, it is to be placed in the pipe tunnel, and as high as possible in the pipe tunnel. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves.
(2) If there is only one main bilge line and a pipe tunnel is not provided, the main is to be placed in a space that is not prone to mechanical damage, such as double bottom ballast tanks and void tanks, etc. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves and the valves are to be located in an accessible dry compartment.
(3) If there are two main bilge lines, each cargo hold is provided with a branch bilge suction connected to each main bilge line respectively, and remotely controlled valves are fitted on each branch bilge suction line.
3.9.1.2 The main bilge line for cargo holds is to be dimensioned as the machinery spaces main bilge line.
3.9.1.3 The main bilge line for cargo holds is to be fitted with a shut-off valve in the machinery spaces.

### 3.9.2 Valves
3.9.2.1 The remotely controlled valves in branch bilge suction lines are to be screw-down non-return valves or shut-off and non-return valves connected in series.

### 3.9.3 Pumps
3.9.3.1 Operating indications of the remotely controlled bilge and ballast pumps are to be provided at the remote control panel.

## Section 10 AIR, OVERFLOW AND SOUNDING PIPES

### 3.10.1 General requirements

3.10.1.1 The cargo mentioned in this Section is the oils having a flash point above 60℃(closed cup test).
3.10.1.2 Air, overflow and sounding pipes are to be made of steel or other approved material.
3.10.1.3 Nameplates are to be affixed to the upper ends of all air and sounding pipes.
3.10.1.4 In addition to complying with the requirements of this Section, air pipes are to be in compliance with the requirements in 1.8.7.5 of PART TWO of the Rules.

### 3.10.2 Arrangement of air pipes

3.10.2.1 Air pipes are to be provided for tanks intended to carry water, oil fuel and lubricating oil, and also for cofferdams and pipe tunnels. The shaft tunnel is to be provided with air pipes if necessary. Air pipes are to be fitted at the highest part of the tanks and far apart from the filling pipes.
3.10.2.2 Tanks having top plates not less than 7 m either in length or in width are to be provided with two or more air pipes arranged suitably apart. Where such arrangements are impracticable due to special circumstances, one air pipe is acceptable provided that effective venting is guaranteed. Where the tank top is of unusual or irregular profile, the number and positions of the air pipes will be decided in each case.
3.10.2.3 Tanks with cathodic protection are to have air pipes fitted forward and aft.
3.10.2.4 All double bottom tanks are to be fitted with air pipes. The double bottom tanks extending from side to side of the ship are to be fitted with air pipes led from both sides. For the double bottom tanks with less breadth at the ship's bow and stern, however, only one vent pipe may be fitted, provided that this single pipe can ensure the effective venting.
3.10.2.5 The arrangement of the air piping is to be such that in the event of any one of the tanks being damaged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes.
3.10.2.6 Location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are to be such that in the event of a broken vent pipe this will not directly lead to the risk of ingress of seawater splashes or rainwater.
3.10.2.7 Following ships are exempted from the provisions of 3.10.2.6 of this Section:
(1) ships for coastal service and services lower than coastal service;
(2) cargo ships of less than 500 gross tonnage.

### 3.10.3 Termination of air pipes

3.10.3.1 Air pipes to the following tanks and cofferdams are to be led to the open above the freeboard deck:
(1) fuel oil tanks;
(2) cargo tanks;
(3) heated lubricating oil tanks and hydraulic oil tanks;
(4) tanks, situated outside machinery spaces, which are not fitted with overflow pipes and can be pumped up;
(5) cofferdams adjacent to fuel oil tanks or cargo tanks.
3.10.3.2 Air pipes to the following tanks and cofferdams other than those prescribed in 3.10.3.1 of this Section are to be led to above the bulkhead deck:
(1) double bottom tanks;
(2) deep tanks extending to shell plating;
(3) tanks which can be directly flooded from the outboard and seawater case;
(4) other cofferdams.
3.10.3.3 Air pipes from lubricating oil tanks or fuel oil draining tanks with a volume less than 0.5 $m^3$ and which cannot be pumped up may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.
3.10.3.4 The open ends of air pipes to oil fuel and cargo tanks are to be situated on the open deck where no danger will be incurred from issuing oil or vapor.
3.10.3.5 The open ends of air pipes to oil fuel and cargo tanks are to be furnished with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.
3.10.3.6 The wire gauze diaphragm at the open ends of air pipes is to have a clear area not less than the cross-sectional area required for the air pipe.

### 3.10.4 Size of air pipes

3.10.4.1 In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to each tank is not to be less than 25% greater than the effective area of the respective filling pipes. In any case, the internal diameter of air pipes is not to be less than 50 mm. When an air pipe serves several tanks, the sectional area of the air pipe is to be at least the combined area of the largest air pipes for two tanks.

3.10.4.2 Where overflow pipes are fitted as specified in this Section, the sectional area of the air pipes is to be at least 20% of that of the filling pipes.

When an air pipe serves several tanks all having overflow pipes as specified in this Section, the sectional area of the air pipe is to be at least 20% of the combined area of the two largest filling pipes for the separate tanks.

3.10.4.3 For ships navigating in ice, the cross-sectional area of air pipes is to be adequately increased.

3.10.4.4 Where tanks form part of the structure of the ship, the wall thickness of air pipes is to comply with Table 2.2.2.6(1) of this PART.

3.10.4.5 Air pipes to shaft tunnels and pipe tunnels are to have an internal diameter not less than 75 mm.

3.10.4.6 The internal diameter of air pipes of tanks is not to be less than 50 mm. For gravity filling tanks with a volume less than $0.5m^3$, smaller diameter air pipes may be used.

### 3.10.5 Arrangement of overflow pipes

3.10.5.1 All tanks which can be pumped up are to be fitted with overflow pipes, when the liquid pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable, or when the sectional area of the air pipe is less than that required in 3.10.4.1 of this Section. When an air pipe serves several tanks, the air pipe of one tank is not to be considered as the overflow pipe of another tank, except the shared overflow pipe connected to the overflow tank.

3.10.5.2 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

Overflow pipes from tanks, other than oil fuel and lubricating oil tanks, are to be led to the open or to suitable overflow tanks.

3.10.5.3 A well illuminated sight glass is to be provided in the overflow pipe, and placed on the vertical pipes in readily visible positions, or alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.

3.10.5.4 Shut-off valves or cocks are not allowed to be fitted to the overflow pipes.

### 3.10.6 Size of overflow pipes

3.10.6.1 The sectional area of overflow pipe(s) from each tank is not to be less than 1.25 times that of the filling pipe(s). When an overflow pipe serves several tanks, the sectional area of the overflow pipe is to be at least the combined area of the largest overflow pipes for two tanks.

### 3.10.7 Prevention of cross flow through the overflow pipes

3.10.7.1 Where overflows from deep tanks which are used for the alternative carriage of fuel oil, cargo oil, water ballast, or dry cargo are connected to an overflow main of other tanks, arrangements are to be made to prevent the overflowing of liquid, gases, etc. from other tanks into the deep tank carrying dry cargo, as well as to prevent the overflowing of liquid into other tanks from the deep tank carrying the liquid.

3.10.7.2 The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main.

### 3.10.8 Sounding pipes

3.10.8.1 Sounding pipes are to be provided for all tanks, cofferdams and pipe tunnels as well as

the bilges or bilge wells which are not at all times readily accessible. All sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible.
The sounding pipes are to be fitted as near the suctions as practicable.
3.10.8.2 Other sounding devices may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested satisfactorily, after fitting on board.
3.10.8.3 All sounding pipes exposed to sea and weather are to be provided with permanently attached effective means of closing to prevent the free entry of water.
3.10.8.4 The bottom plating under open ended sounding pipes is to be protected by striking plates of adequate thickness and size.

### 3.10.9 Short sounding pipes

3.10.9.1 In machinery spaces and shaft tunnels where it is not practicable to extend the sounding pipes as mentioned in 3.10.8.1 of this Section, short sounding pipes extending to readily accessible positions above the platform may be fitted. The following requirements are to be complied with:
(1) Sounding pipes are to be easily accessible and are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.
(2) In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space, and are in all cases to be fitted with self-closing devices.

### 3.10.10 Additional requirements to sounding pipes in fuel oil tanks

3.10.10.1 Safe and efficient means of ascertaining the amount of oil fuel contained in any fuel oil tank are to be provided. Where sounding pipes are used, they are not to terminate in any space where the risk of ignition of spillage from the sounding pipe might rise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where it is impracticable to arrange, termination of sounding pipes in machinery spaces may be permitted on condition that the following requirements are met:
(1) an oil-level gauge is provided meeting the requirements of 3.10.10.3 of this Section;
(2) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the oil fuel in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition;
(3) the termination of sounding pipes are fitted with self-closing blanking devices and with a small-diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that oil fuel is not present. Provisions are to be made so as to ensure that any spillage of oil fuel through the control cock involves no ignition hazard.
3.10.10.2 If fuel oil tanks are fitted with overflow pipes or high level alarm installations satisfying requirements, when the sounding pipes are terminated in machinery spaces, only above-mentioned requirements of 3.10.10.1(2) and (3) are to be met.
For fuel oil tanks in double bottom tanks, where the sounding pipes are terminated in machinery spaces, the following ships are only to comply with above-mentioned requirements of 3.10.10.1(2) and (3):
(1) ships for coastal service and services lower than coastal service;
(2) cargo ships of less than 500 gross tonnage.
3.10.10.3 Other oil-level gauges may be used in place of sounding pipes subject to the following conditions:
(1) in passenger ships, such gauges are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel;
(2) in cargo ships, the failure of such gauges or overfilling of the tank is not to permit release of fuel into the space. The use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks is permitted. The use of cylindrical gauge glasses is prohibited.

### 3.10.11 Additional requirements to sounding pipes in lubricating oil tanks

3.10.11.1 In general, means of ascertaining the amount of lubricating oil contained in any lubricating oil tank are to comply with the requirements of 3.10.10 of this Section. However, the requirements of 3.10.10.1(1) and 3.10.10.1(3) need not be applied on condition that the sounding

pipes terminating in machinery spaces are fitted with appropriate means of closure.

### 3.10.12 Additional requirements to sounding pipes in other flammable oil tanks

3.10.12.1 For flammable oil tanks in spaces where means of ignition are present, means of ascertaining the amount of flammable oil contained in any flammable oil tank are to comply with the requirements of 3.10.10 of this Section.
3.10.12.2 For flammable oil tanks in other locations, if oil-level gauges are used in place of sounding pipes, at least the requirements of 3.10.10.3(2) are to be complied with.

### 3.10.13 Size of sounding pipes

3.10.13.1 Sounding pipes are not to be less than 32 mm in bore and those of heavy fuel oil tanks are not to be less than 50 mm in bore. Sounding pipes passing through compartments or spaces where the temperatures contemplated are 0℃ or below, are not to be less than 65 mm in bore.

## Section 11 VENTILATION

### 3.11.1 General requirements

3.11.1.1 Machinery spaces of category A are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.
Any other machinery space is to be adequately ventilated appropriate for the purpose of that machinery space.
Ventilators of machinery spaces required to be continuously ventilated are to be of a height of coaming complying with the relevant requirements of 1.8.7.4(6), PART TWO of the Rules without having to fit weathertight closing appliances, so that they can be used in all weather conditions. However, where due to vessel size and arrangement this is not practicable, lesser heights for ventilator coamings may be accepted with provision of weathertight closing appliances in accordance with the requirements of 1.8.7.4(7), PART TWO of the Rules in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.
3.11.1.2 All ventilator cowls for boiler rooms are to be fitted with rotating devices so that they may be turned and locked in any desired direction.
3.11.1.3 Effective means of ventilation are to be provided for all lamp-rooms, paint lockers and other compartments used for the storage of inflammable substances, explosives or where toxic or inflammable gases may accumulate.
3.11.1.4 When ventilation pipes pass through other compartments, relevant requirements on fire division and damage stability are to be complied with.

### 3.11.2 Ventilators

3.11.2.1 The ventilators are to comply with the relevant requirements in 1.12.7.4, PART TWO of the Rules.

### 3.11.3 Ventilator cowls

3.11.3.1 Ventilator cowls are to be placed on the exposed deck and located as far from exhaust outlets, sky-lights and companionways as possible.

### 3.11.4 Ventilation of emergency generator rooms

3.11.4.1 The following requirements apply to ventilation louvers which can be closed for emergency generator rooms and to closing appliances where fitted to ventilators serving emergency generator rooms:
(1) Ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic / pneumatic / electric) and are to be operable under a fire condition.
(2) Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where

hand-operation is provided.
(3) Power-operated ventilation louvers and closing appliances are to be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel. Power-operated ventilation louvers and closing appliances are to open automatically whenever the emergency generator is starting / in operation.
(4) It is to be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open / closed) is to be indicated at this position. Such closing is not to be possible from any other remote position.

# CHAPTER 4 MACHINERY PIPING SYSTEMS

## Section 1 GENERAL PROVISIONS

### 4.1.1 Application

4.1.1.1 Unless stated otherwise, the requirements of this Chapter apply to machinery piping systems for ships.

### 4.1.2 Materials

4.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

4.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential for the safety of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see the relevant requirements of 2.4.3 of this PART.

### 4.1.3 Plans and documents

4.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

## Section 2 OIL FUEL SYSTEMS

### 4.2.1 General requirements

4.2.1.1 Oil fuels for use in ships are to comply with the relevant provisions contained in 1.2.7 of this PART.

4.2.1.2 Drip trays are to be provided under the oil tanks which do not form part of the hull structure, pumps, filters, boiler burners and all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment. Oils in the drip trays are to be drained to special sludge tanks, and if the sludge tanks are situated in double bottom tank, shut-off valves or other reliable means of isolation are to be fitted to the drain pipes to prevent sea water entering tank through drain pipes after double bottom tank is damaged. Drain pipes are to be mutual independent from the tank overflow system.

4.2.1.3 The gaskets used for joining covers and manholes of fuel oil tanks and for joining the flanges of fuel pipes are to be made of oil-proof or heat-resistant material.

4.2.1.4 For motor ships burning oil fuel which has to be purified by purifiers, two oil fuel purification units and heating units are to be provided, one of which is a standby.

4.2.1.5 The spaces in which the burning appliances of boilers and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

4.2.1.6 In addition to the local controls, the power supply to all independently driven oil fuel transfer pumps, boiler oil fuel pumps, diesel engine fuel pumps and oil separators is to be capable of being stopped from a readily accessible position outside the spaces in which they are situated.

4.2.1.7 The oil fuel systems of diesel engines for heavy oil are to be provided with immediate change-over devices for diesel oil.

4.2.1.8 Two fuel oil service tanks or equivalent arrangements, for each type of fuel used on board, necessary for propulsion and essential systems are to be provided. Each tank is to have a capacity for at least 8 h operation at sea, at maximum continuous rating of the propulsion plant and normal operating load of the generating plant associated with that tank.

The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

4.2.1.9 A service tank as described in 4.2.1.8 of this Section is a fuel oil tank which contains only fuel of a quality ready for use, i.e. fuel of a grade and quality that meet the specification required by the equipment manufacturer. A service tank is to be declared as such and not to be used for any other purpose. Use of a settling tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an “equivalent arrangement” to two service tanks.

Examples of application for the most common systems are shown below:

(1) Example 1

① Requirement normally to be followed – main and auxiliary engines and boiler(s) operating with heavy fuel oil (HFO) (one fuel ship)

| | | |
|---|---|---|
| HFO service tank<br>Capacity for at least 8 h<br>Main engine + Auxiliary engine + Auxiliary boiler | HFO service tank<br>Capacity for at least 8 h<br>Main engine + Auxiliary engine + Auxiliary boiler | MDO tank<br>For initial cold starting or repair work of engines/boiler |

② Equivalent arrangement

| | |
|---|---|
| HFO service tank<br>Capacity for at least 8 h<br>Main engine + Auxiliary engine + Auxiliary boiler | MDO service tank<br>Capacity for at least 8 h<br>Main engine + Auxiliary engine + Auxiliary boiler |

This arrangement only applies where main and auxiliary engines can operate with heavy fuel oil under all load conditions and, in the case of main engines, during manoeuvring.

For pilot burners of auxiliary boilers if provided, an additional marine diesel oil tank for 8 h may be necessary.

(2) Example 2

① Requirement normally to be followed – main engine(s) and auxiliary boiler(s) operating with HFO and auxiliary engine operating with marine diesel oil (MDO)

| | | | |
|---|---|---|---|
| HFO service tank<br>Capacity for at least 8 h<br>Main engine +<br>Auxiliary boiler | HFO service tank<br>Capacity for at least 8 h<br>Main engine +<br>Auxiliary boiler | MDO service tank<br>Capacity for at least 8 h<br>Auxiliary engine | MDO service tank<br>Capacity for at least 8 h<br>Auxiliary engine |

② Equivalent arrangement

| | | |
|---|---|---|
| HFO service tank<br>Capacity for at least 8 h<br>Main engine +<br>Auxiliary boiler | MDO service tank<br>Capacity for at least the highest of:<br>• 4 h Main engine + Auxiliary engine + Auxiliary boiler, or<br>• 8 h Auxiliary engine + Auxiliary boiler | MDO service tank<br>Capacity for at least the highest of:<br>• 4 h Main engine + Auxiliary engine + Auxiliary boiler, or<br>• 8 h Auxiliary engine + Auxiliary boiler |

The arrangements in (1)② and (2)② apply, provided the propulsion and vital systems which use two types of fuel support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

4.2.1.10 For ships in restricted water service, the capacity of each fuel oil service tank required by 4.2.1.8 of this Section may be reduced according to different situations but no less than 4 h.

4.2.1.11 The following ships are exempt from 4.2.1.8 of this Section:

(1) ships in sheltered water service;

(2) cargo ships less than 500 gross tonnage.

**4.2.2 Oil burning units of boilers**

4.2.2.1 Auxiliary boilers for essential services in this Chapter are those for the purpose of supplying steam to auxiliary machineries as to ensure safe navigation of ships.

4.2.2.2 Main boilers and auxiliary boilers for essential services and for heating of heavy fuel oil are to have not less than two oil supply units, each unit generally comprising a pressure pump, a filter and a heater (if needed). The capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action. Where an exhaust gas boiler is capable of supplying steam for essential purposes, a single oil supply unit may be accepted. For a composite boiler whose exhaust side can provide steam of essential services, a single oil supply unit may also be accepted.

For cargo ships in and within greater coastal service or passenger ships in sheltered water service, if a complete spare pressure pump which is readily accessible and can easily be installed is fitted,

the pressure pump in one oil supply unit may not be required.
For cargo ships of less than 500 gross tonnage, only one oil supply unit is to be fitted.
4.2.2.3 Oil burning unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.
4.2.2.4 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners.
4.2.2.5 A starting-up oil fuel unit, which does not require power from shore, is to be provided for main boilers.
4.2.2.6 Where boiler burners are provided with steam purging and/or atomizing connections, the arrangements are to be such that oil fuel cannot find its way into the steam system.
4.2.2.7 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut out.
4.2.2.8 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control. In the case of oil-fired boilers of automatic controls, the relevant requirements of PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships are also to be complied with.
4.2.2.9 In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically, and audible and visual warnings are given. For small auxiliary top-fired boilers, this requirement may be dispensed with.
4.2.2.10 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.
4.2.2.11 For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

### 4.2.3 Oil fuel pumps, filters and isolating valves

4.2.3.1 Where an oil fuel booster pump is fitted, one main supply pump of sufficient capacity is to be provided for the main engine at its maximum continuous output and one standby pump of sufficient capacity is to be provided for normal navigation of the ship. Such a standby pump is to be independently power driven and capable of being ready for immediate use. Where two or more main engines are fitted, each with its own booster pump, only one standby pump connected ready for immediate use is needed, or alternatively, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.
For cargo ships in and within greater coastal service or passenger ships in sheltered water service, if a complete spare pump which is available for installation and connection is fitted, standby pump is not required.
For cargo ships of less than 500 gross tonnage, neither standby pump nor spare pump is required.
4.2.3.2 Where pumps are provided for fuel valve cooling, the arrangements of standby ones are to be in accordance with 4.2.3.1 of this Section.
4.2.3.3 Oil fuel filters are to be fitted in the oil fuel supply lines to the diesel engines, and their arrangement are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.
4.2.3.4 Oil filters fitted in parallel for the purpose of enabling cleaning without distributing oil supply to engines (e.g. duplex filters) are to be provided with arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filters/filter chambers are to be provided with suitable means for venting when put into operation and depressurizing before being opened.
Valves or cocks with drain pipes led to a safe location are to be used for this purpose.
4.2.3.5 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided. Any suitable pump in connection with fuel transfer system may be accepted as the standby pump.
4.2.3.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump or other appropriate tanks, and to effectively limit the pump discharge pressure to the design pressure of the system.
4.2.3.7 Valves or cocks are to be interposed between the pumps and the suction and discharge

pipes, in order that any pump may be shut off for opening up and overhauling.

4.2.3.8 In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. The means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines. The means of isolation are to be capable of reliable manual closing.

4.2.3.9 The redundancy requirements for fuel oil and hydraulic oil systems and electronic control system of electronically controlled diesel engine are to comply with the relevant requirements of paragraphs 2.1.3 and 2.2.3, Appendix 2, Chapter 9 of this PART.

### 4.2.4 Oil fuel piping

4.2.4.1 Oil fuel piping is to be entirely separate from other piping systems. The arrangements are to be such that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which are used for the carriage of fresh water. Where it is necessary to connect the fuel pipes to ballast systems, they are to be fitted with blanking flanges or other effective isolating devices.

4.2.4.2 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.2.4.3 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions above the working platform.

4.2.4.4 Oil fuel lines are not to be located immediately above or near units of high temperature, including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by 1.3.6.3, Chapter 1 of this PART. As far as practicable, oil fuel lines are to be arranged far apart from hot surfaces, electrical installations or other sources of ignition and are to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems is to be kept to a minimum.

4.2.4.5 Pipes conveying heated oil to boilers under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted parts. The number of flanged joints is to be kept to a minimum. The flanges are to be machined. The jointing material is to be oil proof and impervious to oil heated to 150°C, and is to be as thin as possible. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 1.37 MPa or design pressure, whichever is the greater.

4.2.4.6 The short joining lengths of pipes to the burners from the control valves at the boiler may have threaded cone unions of robust construction.

4.2.4.7 Flexible hoses may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

4.2.4.8 Oil fuel pipes and their valves and fittings are to be of steel or other equivalent material. Nodular graphite cast iron may be used for valves under static head fitted on the outside of fuel tank walls. Grey cast iron valves may be used in oil fuel piping with design pressure of less than 0.7 MPa and design temperature of less than 60℃.

Restricted use of flexible pipes is permissible in some positions. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

### 4.2.5 Oil fuel arrangements and fuel oil tanks

4.2.5.1 As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are not to be placed in a concealed position so that defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

4.2.5.2 Every oil fuel pipe, which, if damaged, would allow oil to escape from a storage, settling or daily service tank situated above the double bottom are to be fitted with a cock or valve directly on the tank or short pipe welded to the oil tank bulkhead with a length not exceeding the value obtained from the following formula. Such valves or cocks are to be capable of being closed locally as well as cable of being closed from safe and easily accessible positions outside the spaces where these tanks are situated. In the case of tanks having a capacity of less than 0.5 m3, remotely controlled closing devices may be omitted.

$$L = 0.8D + 80 \quad \text{mm}$$

where: $L$ – length of short pipe, in mm;

$D$ – outside diameter of steel pipe, in mm.

Remote shut-off control of oil fuel valves for emergency generating set and emergency fire pump is to be separated from those of other valves.

In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves on the tank are to be fitted but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

4.2.5.3 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.2.5.2 of this Section.

4.2.5.4 Fuel oil tanks are not to be situated immediately above boilers or other highly heated surfaces. Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

4.2.5.5 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is to preferably have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces are to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they are not to contain oil fuel having a flashpoint of less than 60℃ (closed cup test).

In general the use of free-standing fuel oil tanks is to be avoided. When such tanks are employed the use are to be prohibited in category A machinery spaces on passenger ships. Where permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank.

4.2.5.6 Settling tanks are to be provided with means for draining water from the bottom of the tanks. If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.2.5.7 Drain valves or cocks fitted to the fuel oil tanks are to be of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.2.5.8 In ships of 400 gross tonnage and above, oil is not to be carried in a forepeak tank or a tank forward of the collision bulkhead. All ships of less than 400 gross tonnage are to comply with the above mentioned provisions so far as it is reasonable and practicable.

4.2.5.9 Location of fuel tanks in cargo area on oil and chemical tankers

On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60℃ and/or toxic liquid cargoes[①] fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within nor extend partly into the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block.

They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements to hazardous area classification must however be met.

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank as shown in Figure 4.2.5.9.

[①] Toxic liquid cargoes include those for which toxic vapour detection is specified in column "k" of the table of chapter 17 of the IBC Code.

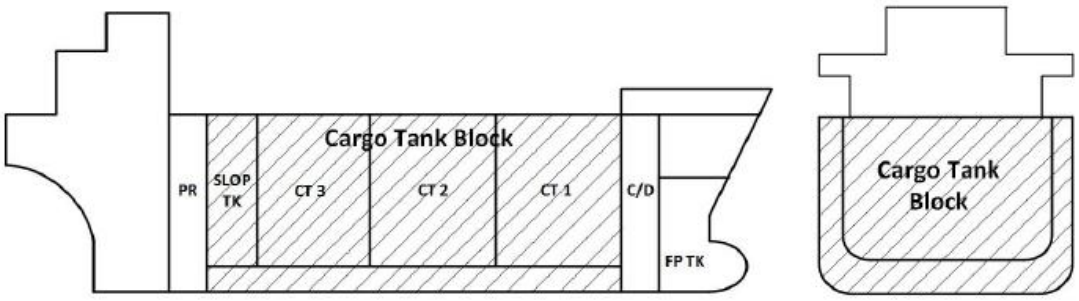



**Figure 4.2.5.9**

### 4.2.6 Filling piping

4.2.6.1 Fuel filling is to be effected by means of permanently installed lines. The filling pipes are to be led to a level as low as practicable inside the tank.

4.2.6.2 Where filling stations are fitted on board, they are to be isolated from other spaces and are to be efficiently drained and ventilated. Filling stations are to be so arranged that filling can be performed safely from both sides of the ship.

4.2.6.3 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

### 4.2.7 Oil fuel (lubricating oil) heating

4.2.7.1 The heating media used for oil fuel (lubricating oil) tanks, heaters or oil separators are not to be more than 220℃ in temperature. Fuel oil (lubricating oil) in storage tanks is not to be heated to temperatures within 10℃ below the flash point of the fuel oil (lubricating oil), except that where oil fuel in service tanks, setting tanks and any other tanks in supply system is heated all of the conditions in 3.2.1.5(1) to (5) of Chapter 3 of PART SIX of the Rules for Classification of Sea-going Steel Ships are satisfied.

4.2.7.2 The exhaust drains from steam or hot water pipes used for heating the oil fuel (lubricating oil) are to be led to a separate observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil.

4.2.7.3 Relief valves are to be fitted on the oil side of heaters and the discharge from the relief valves is to be led to the suction of a related pump or to a safe position.

4.2.7.4 The oil fuel pipes and oil transfer pipes intended for conveying heated oil fuel are to be provided with suitable heating means if necessary.

4.2.7.5 Oil fuel (lubricating oil ) tanks in which oil is heated and heaters are to be provided with suitable means for ascertaining the temperature of the oil.

4.2.7.6 Where steam heaters or heaters using other heating media are provided in fuel or lubricating oil systems, they are to be fitted with at least a high temperature alarm or low flow alarm in addition to a temperature control, except, where the temperature dangerous for the ignition of the medium cannot be reached.

4.2.7.7 Electric heating of fuel oil or lubricating oil are to be avoided as far as practicable.

When electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In order to avoid in any case element surface temperature of 220℃ and above, a safety temperature switch, independent from the automatic control sensor, is to be provided. The safety switch is to cut off the electrical power supply in the event of excessive temperature, and is to be provided with manual reset.

4.2.7.8 The exhaust gas of diesel engines is not to be directly used for heating oil fuel.

### 4.2.8 Alternative carriage of oil fuel and water ballast

4.2.8.1 In general, in oil tankers of 150 gross tonnage and above, all passenger ships and other ships of 4,000 gross tonnage and above, no ballast water is to be carried in fuel oil tanks. Where it is necessary to carry ballast water in fuel oil tanks, suitable means are to be provided for preventing pollution of the sea by oily-water ballast.

4.2.8.2 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, each settling or service tank fitted is to have a capacity sufficient to permit 12 h

normal service, otherwise the suction lines of these compartments are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

### 4.2.9 Deep tanks for the alternative carriage of oil, water ballast or dry cargo

4.2.9.1 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, blank flange or other positive means of closing is to be provided for isolating the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the deep tank is used for dry cargo, and for isolating the bilge suction pipes when the deep tanks are used for oil or water ballast.

4.2.9.2 If the deep tanks are connected to an overflow system, the arrangements are to be such that liquid or vapor from other tanks cannot enter the deep tanks when dry cargo is carried in them.

### 4.2.10 Separation of cargo oils from oil fuel

4.2.10.1 Pipes conveying vegetable oils or similar cargo oils are not to be led through fuel oil tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils.

### 4.2.11 Arrangements for other flammable oils

4.2.11.1 The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board. In locations where means of ignition are present, such arrangements are at least to comply with the provisions of 4.2.4.8 and 4.2.5.4 of this Section, and with the relevant provisions contained in Section 10 of Chapter 3 of this PART.

## Section 3 STEAM PIPING SYSTEMS

### 4.3.1 Arrangement

4.3.1.1 In general, steam pipes are not to be led through lamp rooms, paint lockers and cargo spaces, but where it is impracticable to avoid this arrangement, the pipes in way of cargo spaces are to be well protected from mechanical damage, and pipe joints are to be as few as practicable and preferably butt welded.

4.3.1.2 Where steam pipes subject to a working pressure exceeding 0.98 MPa are placed near to the fuel oil tank, the clearance space between the pipe and the external surface of the tank is in general to be at least 250 mm.

4.3.1.3 Steam pipes are to be arranged in visible and accessible positions in the machinery spaces. Steam pipes, except those used for preheating and sea chest blow-off services, are in general not to be led under the floor plates in machinery spaces.

4.3.1.4 Where two or more boilers are interconnected by steam pipe or pipes, a screw-down non-return valve is to be provided in the steam pipe of each boiler. Valves intended to drain condensate are to be fitted in the pipe length between these valves.

### 4.3.2 Condensate drainage

4.3.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°. Arrangements are to be made for ready access to the drain valves or cocks.

A by-pass line is to be provided where the condensate trap is installed.

### 4.3.3 Thermal expansion stresses

4.3.3.1 For steam pipes subject to a working temperature exceeding 350℃, special consideration is to be given to stress due to thermal expansion and to technique of installation.

## Section 4 FEED, BLOW-OFF AND CONDENSATE SYSTEMS

### 4.4.1 Feed pumps

4.4.1.1 Two or more power driven feed pumps are to be provided for main and auxiliary boilers for essential services or steam auxiliary boilers for heating heavy oil. These feed pumps are to be of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

For cargo ships in and within greater coastal service or passenger ships in sheltered water service, auxiliary boilers may be provided with one feed pump and one spare pump which is available for installation and connection.

For cargo ships of less than 500 gross tonnage, standby pump or spare pump need not be fitted.

4.4.1.2 Forced circulation boilers are to be provided with two independently driven circulating pumps, one of which is used as a stand-by pump. For auxiliary forced circulation boilers not used for essential services, one circulating pump will be accepted.

4.4.1.3 Where a harbor feed pump is provided, it may be used for other purposes, but in no case is it to be used for oil transferring or for discharging oily bilges. Furthermore, a suitable arrangement is to be provided to prevent the contamination of feed from sea water.

### 4.4.2 Feed piping

4.4.2.1 Two feed water systems are to be provided for main and auxiliary boilers for essential services, including feed pumps. The feed systems are to be of sufficient capacity to supply feed water to the boilers with any one system out of action. Only one feed water system may be provided for steam generators heated by steam where the steam for essential services is capable of being supplied simultaneously from another sources.

For cargo ships in and within greater coastal service, passenger ships in sheltered water service or cargo ships of less than 500 gross tonnage, auxiliary boilers may be provided with only one feed water system.

Feed water systems are to be so arranged that the feed water cannot be contaminated by oil or oily water.

4.4.2.2 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, so that any pump may be shut off and opened up for overhaul.

### 4.4.3 Reserve feed water

4.4.3.1 All ships fitted with main boilers and auxiliary boilers for essential services are to be provided with tanks of sufficient capacity for reserve feed water.

4.4.3.2 For main boilers in ships, one or more evaporators of adequate capacity are to be provided to cover the losses of feed water in the system. In the case of auxiliary boilers for essential services in ships, evaporators are to be installed as necessary.

### 4.4.4 Condensate pumps

4.4.4.1 At least two power driven condensate pumps, one of which is a standby pump, are to be provided for dealing with the condensate from the main and auxiliary condensers. Independent feed pumps may be accepted as stand-by condensate pumps.

For cargo ships in and within greater coastal service or passenger ships in sheltered water service, auxiliary boilers may be provided with one condensate pump and one spare pump which is available for installation and connection.

For cargo ships of less than 500 gross tonnage, standby pump or spare pump need not be fitted.

### 4.4.5 Blow-off piping

4.4.5.1 The internal diameter of the blow-off pipes is to comply with the requirements of 6.3.7.2 of this PART. Valves or cocks in the blow-off piping, situated at the ship's bottom or ship's sides, are to be arranged and constructed according to the provisions contained in 2.8.9.2 and 2.8.9.3 of this PART.

4.4.5.2 The blow-off pipes of two or more boilers may be connected to a common discharge, but the blow-off pipe for each boiler is to be fitted with a non-return valve. It is recommended that a throttle washer be fitted to the blow-off pipe.

## Section 5 COOLING WATER SYSTEMS

### 4.5.1 Cooling water pumps

4.5.1.1 For motor ships, where only one main engine is fitted, a main cooling pump of sufficient capacity to maintain supply of water at the maximum continuous output of the machinery and a standby cooling pump of sufficient capacity to supply cooling water under the normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use. Where more than one main engine is fitted, each with its own cooling water pump, a complete spare pump may be accepted as a standby cooling water pump.

For cargo ships in and within greater coastal service or passenger ships in sheltered water service, the required standby cooling water pump may be substituted by other pumps of sufficient capacity or a complete spare pump available for installation and connection.

For cargo ships of less than 500 gross tonnage, standby pump or spare pump required in 4.5.1.1 of this PART need not be fitted.

4.5.1.2 In steam ships, in addition to the main circulating pump for the condenser, there is to be an alternative supply from an emergency pump having a capacity sufficient to maintain the proper control of the ship (in general not to be less than 30% of that of the main circulating pump). If the main circulating pump unit consists of two independently power-driven pumps of approximately equal capacity, the emergency pump may be dispensed with.

Where a sea inlet scoop arrangement is fitted in lieu of the main circulating water pump, in addition to one independently power-driven circulating water pump having a capacity of at least 30% of that of the maximum required by circulation, a connection to the largest available pump suitable for circulation duties is to be fitted to provide the second means of circulation when the ship is maneuvering.

4.5.1.3 Where each essential auxiliary engine is fitted with a built-in cooling water pump, the standby pump may be dispensed with. If two or more auxiliary engines are supplied with cooling water from a common system, a standby cooling water pump is needed. The standby cooling water pump may be substituted by other pumps of sufficient capacity.

4.5.1.4 Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

### 4.5.2 Piping and fittings

4.5.2.1 The cooling water piping for diesel engines is to be capable of effectively regulating the inlet cooling water temperature. For closed circuit fresh water cooling system, expansion tanks are to be provided and it is recommended that an alarm for high temperature be fitted.

4.5.2.2 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge. When discharge from the relief valves is to find its way into the bilge, the valves are to be fitted in readily visible positions above the floor. The arrangement is to be such that any discharge from the relief valves will also be readily visible.

4.5.2.3 Not less than two sea inlets, which are to be fitted on both sides of the ship as far as practicable, are to be provided for the cooling water pumps of sea water cooling system or circulating system. The suction of any cooling water pump or circulating pump under normal service conditions is to be supplied from either one of the sea inlets.

4.5.2.4 Provision is to be made for the protection of all equipment cooled by sea water against corrosion.

4.5.2.5 Strainers are to be provided to the suction pipes between the sea inlets and the suctions of sea water cooling pumps. The strainers are to be so arranged that they can be cleaned without interrupting the cooling water supply.

4.5.2.6 When it is necessary, the main diesel engine with closed circuit fresh water cooling system is to be provided with suitable means for warming the engine before starting. Alternatively, means to inter-connect the fresh water cooling system for main engine to that for auxiliary engines are acceptable.

## Section 6 LUBRICATING OIL SYSTEMS

### 4.6.1 Lubricating oil pumps

4.6.1.1 Main engines and their transmission gearing are to be provided with a main lubricating oil pump of sufficient capacity to maintain supply of lubricating oil at the maximum continuous output of the machinery and a standby pump of sufficient capacity to supply lubricating oil under normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use.

For ships fitted with more than one main engine, only one independently power-driven standby pump fitted is acceptable. Where each main engine and its transmission gearing is fitted with a built-in lubricating oil pump, a complete spare pump available for installation and connection may be accepted as an independently power-driven standby pump.

For ships in restricted service, if the output of main engine and its transmission gearing is not more than 440 kW, standby pump need not be fitted.

4.6.1.2 Where each essential auxiliary engine and its transmission gearing is fitted with a built-in lubricating oil pump, the standby pump may be dispensed with. If two or more auxiliary engines and their transmission gearings are connected to a common lubricating oil system, a standby pump is needed.

### 4.6.2 Piping and fittings

4.6.2.1 The lubricating oil piping is to be entirely separate from other piping systems. A common lubricating oil system is not to be in use for diesel engines and gear boxes.

4.6.2.2 Provision is to be made for the efficient filtration of the lubricating oil. For main propulsion machinery, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required in normal operation of ships. For generating sets, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required by generating sets under normal work load. Pressure gauges are to be fitted on both ends of lubricating oil filters or strainers. Proposals for fitting an emergency automatic by-pass device in high speed engines are to be submitted for special consideration.

Magnetic strainers are to be provided for high-powered main turbines and their reduction gears.

4.6.2.3 A relief valve is to be fitted on the lubricating oil pump discharge if the pump is capable of developing a pressure exceeding the design pressure of the system. The relief valve is to be such that the discharge oil can find its way to the suction of the pump and the pump discharge pressure is to be effectively limited to the design pressure of the system.

4.6.2.4 Visual and audible alarms are to be provided to give warning of an appreciable reduction in pressure of the lubricating oil.

4.6.2.5 Where two or more diesel engines are fitted, the drain pipes leading from the engine sumps to the lubricating oil drain tanks are to be independent to avoid intercommunication between crankcases.

### 4.6.3 Additional requirements for lubricating oil systems of main turbines and main turbo-generators

4.6.3.1 For main turbines and main turbo-generators in electrically propelled ships, a suitable emergency supply of lubricating oil is to be arranged. For this purpose, either one of the following will be accepted:

(1) The emergency supply may be obtained from a gravity tank holding sufficient lubricating oil to maintain adequate lubrication for not less than 5 min for main turbines, and, in the case of main turbo-generators, until the unloaded turbine comes to rest from the maximum rated running speed. The gravity tank is to be arranged to come automatically into use in the event of a failure of the lubricating oil pump. An alarm device is to be fitted to the gravity tank to give visual and audible warning when the oil in the tank falls to a predetermined level.

(2) The emergency supply may be obtained from a standby pump or an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the main power supply and that they are capable of coming automatically into use.

4.6.3.2 Overflow pipes, which are to be led to the lubricating oil drain tanks, are to be fitted to the gravity tanks and the cross-sectional area of the overflow pipes is not to be less than 1.25 times that of the filling pipes from the lubricating oil pumps. The overflow pipes are to be fitted with

illuminated sight glasses.

### 4.6.4 Lubricating oil arrangements and lubricating oil tanks

4.6.4.1 The separation of lubricating oil tanks from adjacent tanks is to be in compliance with the requirements of 2.8.2 of this PART.

4.6.4.2 The capacity of lubricating oil drain tanks is to be sufficient to hold the oil in the whole system.

Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drain pipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform. If the drain tanks in the double bottom are separated from the shell plating by cofferdams, the shut-off valve mentioned above may be dispensed with.

The oil inlet pipe of the drain tank is to be extended to an adequate depth below the lowest working level and is to be located as wide apart from the outlet as practicable.

4.6.4.3 The pressure lubrication systems are to comply with the requirements of 4.2.4.4, 4.2.4.8, 4.2.5.1, 4.2.5.2, 4.2.5.4 and 4.2.6.3 of this Chapter and the relevant provisions contained in Section 10 of Chapter 3 of this PART.

In the case of tanks having a capacity of less than 0.5 $m^3$, consideration will be given to the omission of remote controls.

If the designers confirm that an unauthorized operation of the remotely controlled closing valves on the lubricating tanks will jeopardize safe running of the main or eventful auxiliary engines, the remotely controlled device may be omitted.

4.6.4.4 All ships are to be provided with lubricating oil storage tank(s) having an adequate capacity.

4.6.4.5 Heating of lubricating oil is to comply with the relevant requirements of 4.2.7 of this Chapter.

## Section 7 HYDRAULIC TRANSMISSION PIPING SYSTEMS

### 4.7.1 Materials

4.7.1.1 All components in the hydraulic transmission piping systems are to be made of materials which are not corrodible and have no chemical reaction with the hydraulic fluid.

4.7.1.2 The hydraulic fluid is to be of high chemical stability and of good viscosity-temperature property.

4.7.1.3 Main components in hydraulic power transmission system are to be generally made of steel materials. Material test is to be carried out according to the requirements of CCS Rules for Materials and Welding.

### 4.7.2 Piping

4.7.2.1 The hydraulic transmission piping is not to be used for the lubrication of other equipment.

4.7.2.2 The strength of hydraulic pipes and fittings is to be sufficient to withstand the pressure fluctuations which might occur in the system.

4.7.2.3 Strainers and relief valves are to be provided in the hydraulic transmission piping systems. The discharge from the relief valves is in general to be led to the hydraulic fluid tanks.

4.7.2.4 Provision is to be made for de-aeration in the hydraulic piping systems and the hydraulic fluid cylinders, etc. The hydraulic piping is to be so arranged as to avoid the formation of air pockets.

4.7.2.5 Where hydraulic accumulators are provided in the hydraulic systems, overflow valves are to be fitted on the liquid side. Unless otherwise specified, for hydro-pneumatic accumulators, safety valves or fuse plugs are to be fitted on the air side, otherwise they are to be fitted in the supply pipe line, and an isolation valve is not to be provided between the air side of the accumulator and the safety valve or fuse plug.

4.7.2.6 The use of flexible hoses is to comply with the relevant requirements of 2.4.4 of this PART. The flexible hoses are to be so arranged that abrupt bends and twisting will not occur in

the laying of the hoses and they are to be far away from vibration and hot sources.
4.7.2.7 Hydraulic remote control valves for essential service are to be capable of being operated with a hand pump in emergency condition, and indicators showing whether the valves are open or closed are to be provided at their operating positions.
4.7.2.8 The hydraulic transmission piping system for essential services is to be provided with a standby power pump which is to be capable of immediate use.

### 4.7.3 Arrangement
4.7.3.1 Hydraulic units with working pressure above 1.5 MPa are to be placed in separate spaces. If it is impracticable to locate such units in a separate space, adequate shielding is to be provided.

## Section 8 THERMAL OIL SYSTEM

### 4.8.1 General requirements
4.8.1.1 The thermal oil used in the thermal oil system is to be compatible with the oil being heated.
4.8.1.2 Heating of liquid cargoes with flash points below 60°C is to be arranged by means of a separate secondary system, located completely within the cargo area. However, a single circuit system may be accepted on the following conditions:
(1) system is so arranged that a positive pressure in the coil is to be at least 3 m water column above the static head of the cargo when circulating pump is not in operation;
(2) the thermal oil system expansion tank is to be fitted with high and low level alarms;
(3) means are to be provided in the thermal oil system expansion tank for detection of flammable cargo vapors;
(4) valves for the individual heating coils are to be provided with locking arrangement to ensure that the coils are under static pressure at all times.
4.8.1.3 For details of heaters in thermal oil systems, see the relevant requirements of Section 5, Chapter 6 of this PART.

### 4.8.2 Plans and documents
4.8.2.1 The piping and pumping system plans of thermal oil systems are to be submitted for approval.

### 4.8.3 Design and manufacture
4.8.3.1 The installation is generally to comprise at least two circulation pumps and two filters for the thermal oil.
4.8.3.2 In addition to the local operations, the inlet and outlet valves of oil-fired thermal oil heaters and exhaust-fired thermal oil heaters are to be shut off from a readily accessible position outside the compartment where they are situated. As an alternative, an arrangement for quick gravity drainage of the thermal oil contained in the system into a collecting tank is acceptable.
4.8.3.3 Arrangements are to be provided to permit from inside and from outside the heater spaces a quick discharge by gravity of the expansion tank into a suitable tank.
4.8.3.4 The monitoring and protection of thermal oil heaters are to comply with the relevant requirements of 6.5.5, Chapter 6 of this PART.
4.8.3.5 Tubes and pipes for thermal oil are to be seamless steel tubes or welded steel tubes and pipes.
4.8.3.6 Casings of pumps, valves and similar components are to be made of steel or equivalent ductile material. Copper and copper alloys are not to be used for those parts the surface of which is in direct contact with thermal oil so as to prevent oxidation of thermal oil.
4.8.3.7 Thermal oil piping is to have welded connections except that flanges may be used to the limited number necessary for inspection and maintenance. If necessary, suitable devices are to be provided for avoiding oil splash in case of leakage in way of the flanges. Marine steel recess type or plane flanges having a nominal pressure not less than 1.6 MPa are to be used for inlet and outlet pipe connection of thermal oil heaters. In the case of steel plane flanges, wire-reinforced graphite gaskets or expanded graphite composite gaskets are to be used.
Screw joints are not to be used for thermal oil piping.

4.8.3.8 The piping system is to be designed and constructed to permit expansion and contraction without abnormal stressing.
4.8.3.9 Particular attention is to be paid to the insulation of thermal oil piping and heater. Flanges are not permitted to be protected by the insulation material. Insulation material of thermal oil heater and piping is to be of an approved type and, as far as possible, it does not lower than the auto-ignition point of the thermal oil when impregnated by it.
4.8.3.10 The thermal oil system is also to comply with the requirements contained in the relevant Chapters of the Rules.

### 4.8.4 Arrangement

4.8.4.1 Where the thermal oil heaters are located in main and auxiliary machinery spaces, effective means are to be provided to prevent dispersal of thermal oil after leakage, such as coaming plate, etc.
4.8.4.2 The thermal oil circulating pumps are to be arranged for emergency stopping from a position outside the space where they are situated.
4.8.4.3 Drip trays are to be installed under the components of the installation where leakage is liable to occur. These drip trays are to be drained to an appropriate sludge tank.
4.8.4.4 The thermal oil system is to be fitted with an expansion tank of sufficient capacity. The thermal oil expansion tank and pumping plants are to be located in the same space as the thermal oil heaters.
4.8.4.5 Vents from expansion tanks and thermal oil storage tanks of the thermal oil heating plants are to be led to open deck.
4.8.4.6 Thermal oil piping and pumping system are to comply with the relevant requirements of Section 2 of this Chapter. Only one pump supplying thermal oil to the thermal oil expansion tank is acceptable.
4.8.4.7 Thermal oil pipes are not to pass through accommodation spaces nor control stations. Thermal oil piping passing through main and auxiliary machinery spaces is to be restricted as far as possible.
4.8.4.8 Thermal oil heater rooms are to be suitably mechanically ventilated and illuminated.
4.8.4.9 Thermal oil heater rooms are to be fitted with approved automatic fire detection system or fire alarm system.

### 4.8.5 Additional requirements for exhaust-fired thermal oil heaters

4.8.5.1 Exhaust-fired thermal oil heaters are also to comply with the relevant requirements of 6.5.4.5 and 6.5.4.6, Chapter 6 of this PART.

### 4.8.6 Testing

4.8.6.1 Thermal oil system and installation are to be subject to hydraulic and tightness tests according to the relevant requirements contained in Chapters 2 and 6 of this PART.
4.8.6.2 On completion, working tests of the thermal oil system are to be carried out in accordance with the test program.

## Section 9 REQUIREMENTS CONCERNING USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS

### 4.9.1 General requirements

4.9.1.1 In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.
4.9.1.2 Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.
4.9.1.3 The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.
The whole surface of the boilers is to be gas-tight separated from the engine room. The boilers are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, is to be fitted in the cargo pump room or in another room, to be considered as

dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils is to be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the provisions for tankers and with the outlet fitted with a suitable flameproof wire gauze of corrosion resistant material which is to be easily removable for cleaning.

4.9.1.4 Electric, internal combustion and steam (when the steam temperature is higher than 220°C) prime movers of driving pumps, of separators (if any) are to be fitted in the engine room or in another non-dangerous room.

Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted. The glands are to be efficiently lubricated from outside the pump room.

4.9.1.5 Pumps are to be fitted with a pressure relief by-pass from delivery to suction side and it is to be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

4.9.1.6 When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

### 4.9.2 Arrangement

4.9.2.1 The piping for crude oil or slops and the draining pipes for the tray defined in 4.9.2.3 are to have a thickness as shown in Table 4.9.2.1.

**External diameter and thickness of crude oil, slops and draining pipes (mm)**

**Table 4.9.2.1**

| External diameter $d_e$ | Wall thickness $t$ |
|---|---|
| $d_e \leq 82.5$ | $\geq 6.3$ |
| $88.9 < d_e \leq 108$ | $\geq 7.1$ |
| $114.3 < d_e \leq 139.7$ | $\geq 8.0$ |
| $152.4 \leq d_e$ | $\geq 8.8$ |

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ships side of at least 1/5 of the vessel's beam ($B$) amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in 4.9.2.3. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flameproof wire gauze of corrosion-resistant material which is to be easily removable for cleaning.

The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:

(1) injection of inert gas or steam in the duct in case of fire or leakage;

(2) purging of the duct before carrying out work on the piping in case of leakage.

4.9.2.2 In way of the bulkhead to which the duct defined in 4.9.2.1 is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves are to be interlocked with the hood exhaust fans (defined in 4.9.3.1) to ensure that whenever crude oil is circulating the fans are running.

4.9.2.3 Boilers are to be fitted with a tray or gutterway with a suitable height and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.

Such a tray or gutterway is to be fitted with a suitable flameproof wire gauze, made of corrosion resistant 246material and easily dismountable for cleaning. Delivery and return oil pipes are to pass through the tray or gutterway by means of a tight penetration and are then to be connected to the oil supply manifolds.

A quick closing master valve is to be fitted on the oil supply to each boiler manifold.

The tray or gutterway is to be fitted with a draining pipe discharging into a collecting tank in

pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning. The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.

### 4.9.3 Other requirements

4.9.3.1 Boilers are to be fitted with suitable hood in such a way as to enclose as mach as possible of the burners, valves and oil pipes, without preventing on the other side, air inlet to burner register.

The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flameproof wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.

The exhaust fan prime movers are to be placed outside the duct and a gas-tight bulkhead penetration is to be arranged for the shaft.

Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type as required.

4.9.3.2 When using fuel oil for delivery to and return from boilers, fuel oil burning units are to be fitted in the boiler room. Fuel oil delivery to, and returns from, burners are to be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

4.9.3.3 The boiler compartments are to be fitted with a mechanical ventilation plant and are to be designed in such a way as to avoid the formation of gas pockets.

Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants are to be separated from those for service of other compartments and are to be in accordance with relevant requirements of CCS.

4.9.3.4 A gas detector plant is to be fitted with intakes in the duct defined in 4.9.2.1 of this Section, in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

4.9.3.5 Means are to be provided for the boiler to be automatically purged before firing.

4.9.3.6 Independent of the fire extinguishing plant as required in the Rules, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in 4.9.2.3 of this Section. The emission of extinguishing medium is automatically to stop the exhaust fan of the boiler hood.

4.9.3.7 A warning notice is to be fitted in an easily visible position near the boiler front. This notice is to specify that when an explosive mixture is signaled by the gas detector plant defined in 4.9.3.4, the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in 4.9.2.1 of this Section and turn the boilers to normal running on fuel oil.

4.9.3.8 One pilot burner in addition to the normal burning control is required.

## Section 10 EXHAUST PIPELINES

### 4.10.1 Arrangement

4.10.1.1 Uptakes of boilers except exhaust gas boilers are not to be connected with exhaust pipelines of diesel engines.

4.10.1.2 Uptake governors or other means for closing the uptakes are not to be fitted within uptakes or funnels of oil-fired boilers.

### 4.10.2 Silencers

4.10.2.1 The structure of silencers is to be so designed that the internal cleaning and inspection can be carried out easily and these silencers are to be fitted with washing units with compressed air or steam or other cleaning appliances and drainage valves or cocks.
4.10.2.2 The external portion of silencers is to be packed with thermal insulation materials.

### 4.10.3 Water heaters

4.10.3.1 Water heaters fitted on the ducts for exhaust gas and smoke are, in general, to be of open type. If close type water heaters are fitted, the strength calculation is to be in accordance with the relevant requirements in Chapter 6 of this PART.
4.10.3.2 Close type water heaters are to be fitted with relief valves, pressure gauges, water level indicators, etc.
4.10.3.3 On construction, the close type water heaters are to be subject to a hydraulic test of 1.5 times the design pressure and the test pressure is not to be less than 0.4 MPa. The test of relief valves is to be carried out in accordance with the requirements in 6.3.5.3 of this PART.
4.10.3.4 Open type water heaters are to be fitted with a vent pipe of sufficient diameter and the vent pipe is not to be fitted with any closing appliances.

# CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS

## Section 1 GENERAL PROVISIONS

### 5.1.1 Application

5.1.1.1 The requirements of this Chapter apply to oil tankers having the main propelling machinery aft which are intended to carry crude oil and petroleum products having a flash point (closed cup test) not exceeding 60℃. Where ships are intended for the carriage of cargo oil having a flash point (closed cup test) exceeding 60℃, the relevant requirements in Section 8 of this Chapter are to be complied with.

5.1.1.2 In addition to the requirements of this Chapter, piping systems for oil tankers are to comply with the relevant provisions contained in Chapters 2, 3 and 4 of this PART, where applicable.

### 5.1.2 Arrangement of dangerous spaces

5.1.2.1 Diesel engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within cargo tanks, pump rooms, cofferdams or other spaces liable to contain cargo oil or explosive vapors, or in spaces or zones immediately adjacent to cargo oil or slop tanks. The temperature of steam, or other fluid, in pipes (or heating coils) in these spaces is not to exceed 220℃.

### 5.1.3 Steam connections to cargo tanks

5.1.3.1 Where steaming out connections are provided for cargo tanks or cargo pipelines, they are to be fitted with valves of the screw-down non-return type. The main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the cargo tanks.

The steaming pipes are to be so arranged that the steam can be supplied to the upper and lower parts of the tank separately as necessary.

### 5.1.4 Cargo pump room

5.1.4.1 Cargo pump rooms are to be situated within, or adjacent to, the cargo tank area and are to be provided with ready means of access on open deck. Pump rooms are to be totally independent of and to have no direct communication with machinery spaces.

5.1.4.2 In cargo pump rooms any drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

### 5.1.5 Slop tanks

5.1.5.1 In oil tankers, the venting arrangement, level sounding devices, heating systems and the piping for conveying oily water and cargo oil for the slop tanks designated for collecting and treating tank washings and dirty ballast from cargo tanks and other oily water are to comply with the relevant requirements for cargo tanks.

5.1.5.2 Discharge of oily water from slop tanks is to comply with the provisions for the prevention of pollution from ships.

### 5.1.6 Gas freeing equipment

5.1.6.1 Provision is to be made for the gas freeing of cargo tanks when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo tanks. For the purpose of monitoring flammable vapor, portable instruments are to be available on board for gas detection.

### 5.1.7 Earthing of cargo oil pipes

5.1.7.1 Earthing and bonding of cargo tanks and piping systems for the control of static electricity is to comply with the requirements in 1.3.4.11 of PART FOUR of the Rules.

### 5.1.8 Prevention and free of spark

5.1.8.1 The outlets of the exhaust gas pipes for main and auxiliary engines, boilers and other burner equipment are to be located at the sufficient height above the main deck. The horizontal

distance of the outlets from cargo area is not to be less than 10 m. Where internal combustion engine is provided with approved spark arresters, as well as boilers and other burner equipment to be provided with spark arresters, their distance may be reduced to 5 m.

## Section 2 CARGO HANDLING SYSTEM

### 5.2.1 General requirements

5.2.1.1 At least two independently power-driven cargo oil pumps are to be connected to the cargo oil system to pump cargo oil in each cargo tank. The arrangement is to ensure that the operation of other pumps is not affected if any one of the cargo oil pumps is inoperable.

5.2.1.2 If the cargo in cargo tank is lightered by a single deep well pump installed in each cargo tank, an emergency means for pumping out the tank is to be provided in case of failure of deep well pump.

### 5.2.2 Cargo pumps

5.2.2.1 Cargo pumps for the purpose of filling or emptying the cargo tanks are to be used exclusively for this purpose, except that they may be used for crude oil washing , cargo pump room drainage (see 5.3.2.1 of this Chapter) and filling or emptying water ballast in the cargo tanks. They are not to have any connections to compartments outside the range of cargo tanks.

5.2.2.2 Cargo pumps are to be installed in isolated pump rooms.

5.2.2.3 Where cargo pumps are driven by steam engines or turbines having a steam temperature not exceeding 220$^{o}$C, the prime movers may be installed in the pump room.

5.2.2.4 Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump room plating. The glands are to be efficiently lubricated from outside pump room and are to be so designed as to prevent overheating. The seal parts of the glands are to be of materials that will not initiate sparks. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 0.34 MPa before fitting.

5.2.2.5 Cargo pumps installed in cargo pump rooms and driven by shafts passing through pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands and shaft bearings of cargo pumps from outside of pump room. Alarm is to be initiated for excessive temperature of the above-mentioned glands and bearings.

5.2.2.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump, and to effectively limit the pump discharge pressure to the design pressure of the system.

5.2.2.7 Cargo oil pumps are to be capable of being stopped from a suitable position outside the pump room, as well as at the pumps.

5.2.2.8 A pressure gauge indicating the discharge pressure is to be fitted at the delivery side of each cargo oil pump. An additional gauge is to be fitted in the vicinity of the pump control station.

5.2.2.9 The safety requirements for stripping pumps fitted onboard and their piping systems are to be the same as those to cargo oil pumps and their piping systems.

5.2.2.10 Any integral hydraulic and/or electrical system used to drive both cargo and ballast pumps (integral cargo and ballast system) is to comply with the relevant provisions in 2.6.7, Chapter 2, PART FOUR of the Rules.

### 5.2.3 Cargo piping system

5.2.3.1 Cargo oil pipes are to be laid only within the cargo tank area, except for the bow or stern loading and unloading equipment outside cargo tank specified in the following 5.2.3.12.

5.2.3.2 Unless stated otherwise, cargo oil pipes are to be fully independent of other pipes. .

5.2.3.3 Where Cargo tanks and slop tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tanks, so as to minimize the generation of static electricity.

5.2.3.4 Where it is necessary to fill the oil tanks by using the cargo oil suction pipes, a by-pass is to be provided to connect the suction and discharge ends of cargo oil pump. A stop valve is to be fitted on the by-pass.

5.2.3.5 Where the cargo oil piping system is used also as a ballast system for the cargo tanks, a

blank flange or a removable spool piece is to be fitted between the sea chest valve and the cargo oil main, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.
The discharge of oily ballast water is to comply with the requirements for the prevention of pollution from ships.
5.2.3.6 Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected, are to be of steel or ductile material. They are to be of robust construction and strongly supported.
A manually operated shut-off valve is to be fitted to each shore loading/discharging connection.
5.2.3.7 Expansion joints or bends are to be provided, where necessary, in the cargo pipelines.
5.2.3.8 For cargo piping system, means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or slop tank or to the shore facilities.
5.2.3.9 The operating rods for cargo valves in cargo tanks are to be extended to positions above the open deck. In the case of cargo tanks which are located adjacent to below-deck pump rooms or pipe tunnels, the operating rods may be located in these spaces at the bulkhead.
Stuffing boxes are to be fitted where the operating rod passes through the deck or bulkhead and to be so constructed that packing may be renewed from outside the cargo tanks. Indicators are to be provided at the operating hand wheels to show whether the valves are open or closed.
5.2.3.10 Materials used for the friction parts of the valves and operating rods of the cargo oil piping and of flexible couplings in shafts between the cargo pumps and the prime movers are to such as to preclude the possibility of sparking while in operation.
5.2.3.11 Cargo oil pipelines are not to pass through ballast tanks. Where this can not be avoided, the pipes passing through ballast tanks are to have a wall thickness in accordance with the requirements in Table 5.3.4.2 of this Chapter and are to be provided with welded joints.
5.2.3.12 Bow or stern loading and unloading
Where bow or stern loading and unloading connections are provided outside cargo tank area, the arrangements are to be as follows:
(1) Cargo lines for bow or stern loading and unloading are to be installed outside accommodation spaces, service spaces, machinery spaces and control stations, and are to be clearly identified.
(2) Pipe joints outside the cargo area and used for bow or stern loading and unloading are to be welded.
(3) A spectacle flange or a removable spool piece is to be fitted at the connection line between the cargo loading and unloading line and cargo main line in cargo area, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.
(4) The loading and unloading connection is to be fitted with a shut-off valve and a blank flange. Spill containment is to be provided under the loading and unloading manifold.
(5) Arrangements are to be provided for cargo lines outside of the cargo area for easy draining to a slop tank or cargo tank.
(6) Space within 3 m from the oil spill containment boundary and connection mentioned in (4) above is considered to be gas hazardous area and is to be clearly identified.
(7) Fixed deck foam fire-extinguishing system required for cargo area is to effectively protect bow or stern loading and unloading area.

### 5.2.4 Remote control valves

5.2.4.1 Valves on deck and in pump rooms which are provided with remote control are to have local manual operating devices independent of the remote operating mechanism or emergency means for operating the valve actuators in the event of damage to the main hydraulic circuits on deck, such as connections, with isolating valves, fitted to the pipes near the valve actuators as far as possible for coupling to a standby portable pump carried on board.
5.2.4.2 Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank, or alternative means of emptying the tanks in the event of a defective actuator, are to be provided.
It is recommended that the lines to the valve actuators be led vertically inside the tanks from deck, and that connections, with isolating valves, be provided on deck lines for coupling to a standby portable pump carried on board for emergency operation of the valves in the event of damage to the main hydraulic circuits on deck.
5.2.4.3 Indication is to be provided at the remote control stations showing whether the valve is

open or shut.
5.2.4.4 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. The design of the actuators is to be such that contamination of the operating medium with cargo oil cannot take place under normal operating conditions.
5.2.4.5 Compressed air is not to be used for operating actuators inside cargo tanks.
5.2.4.6 For the actuators in cargo tank, the supply tank is to be located as high as practicable above the level of the top of cargo tank, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with high and low level audible and visual alarms.

# Section 3 BILGE, BALLAST AND OTHER PIPING SYSTEMS

### 5.3.1 Pumping arrangements at ends of ship outside ranges of cargo tanks

5.3.1.1 The pumping arrangements in machinery spaces and the forward end of the ship are to comply with the requirements for general cargo ships, unless otherwise specified in this Section.
5.3.1.2 The internal diameter $d_1$ of the bilge main and direct bilge suction in machinery spaces is to be calculated according to the requirements of 3.4.3.1 of this PART. $L$ in the formula may be the ship length reduced by the combined length of the cargo area. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines.
5.3.1.3 The internal diameter $d_2$ of branch bilge suction pipes of machinery spaces is to be in accordance with the requirements in 3.4.3.3 of this PART.
5.3.1.4 Bilge, ballast and oil fuel lines, which are connected to pumps, tanks or compartments at the ends of the ship, are not to pass through cargo tanks or have any connections to cargo tanks or cargo lines, in general, no objection will be made to these lines being led through ballast tanks or void spaces within the range of the cargo tanks.
5.3.1.5 The arrangement of all pumps serving tanks directly adjacent to cargo tanks is also to comply with the requirements to cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter, except for pumps and pipes serving fuel oil tanks located behind cargo tanks and directly adjacent to cargo tanks. Pumps and pipings serving above-mentioned fuel oil tanks may be located in engine room.
5.3.1.6 Unless specified otherwise, the piping system outside cargo area is to be mutual independent from the piping system within cargo area.

### 5.3.2 Cargo pump room drainage

5.3.2.1 Provision is to be made for the drainage of the cargo pump rooms by pump or bilge ejector suctions. Where cargo pumps or cargo stripping pumps are used for this purpose, the bilge suctions are to be fitted with screw-down non-return valves and, in addition, a stop valve is to be fitted on the pump connection to the bilge valve chest.
For oil tankers of less than 150 gross tonnage, cargo pump room bilge may be drained by the manual pump 50 mm in inside diameter of suction.
5.3.2.2 Cargo pump room suctions are not to enter machinery spaces.
5.3.2.3 The bilge drainage of the cargo pump rooms is to comply with the relevant requirements for the prevention of pollution from ships. It is recommended that cargo pump room bilge is to be drained into the slop tanks.
5.3.2.4 All the cargo pump rooms are to be provided with bilge level monitoring devices and suitable synchronous alarm devices

### 5.3.3 Cofferdam drainage within the ranges of cargo tanks

5.3.3.1 The bilge suction equipment of cofferdam is to be installed within the ranges of cargo tanks. The requirements of 5.3.2.1 of this Section are to be complied with, where cargo pumps or cargo stripping pumps are used for drainage. Alternatively, cofferdams may be drained by bilge ejectors.

### 5.3.4 Ballast piping within the range of the cargo tanks

5.3.4.1 Ballast tanks within the range of cargo tanks and ballast pipelines in the double bottom tank are to be provided with separate ballast pumps and pipelines. The ballast pump is to be located in the cargo pump room or other suitable space within the range of the cargo tanks. The arrangement of ballast pumps is also to comply with the requirements for cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter. However, If ballast pump is located in individual ballast pump tank, the requirements of 5.2.2.5 may be exempted.

5.3.4.2 The ballast lines are not to pass through ballast tanks. Where this can not be avoided, the ballast lines passing through cargo tanks are to be heavy gauge steel, having welded or heavy flanged joints. The pipes in cargo tanks are not to be less than the value given in Table 5.3.4.2 in thickness. The number of joints is to be kept to a minimum. Where it is proposed to use material which is more resistant to corrosion than carbon steel, the pipe thickness may be suitably reduced.

**Pipe thickness inside cargo tanks** **Table 5.3.4.2**

| Nominal diameter of pipe①(in mm) | Minimum wall thickness (in mm) |
|---|---|
| 50 | 6.3 |
| 100 | 8.6 |
| 125 | 9.5 |
| 150 | 11.0 |
| 200 and above | 12.5 |

Notes: ① For nominal diameter with the value between those listed in the Table, the corresponding pipe thickness may be calculated by insertion.

5.3.4.3 Expansion bends or bellows, not glands, are to be fitted to the ballast pipes in the cargo tanks.

5.3.4.4 For clean ballast piping, provision may be made for emergency discharge of water ballast by means of a portable spool connection to cargo oil pump and where this is arranged, a screw-down non-return valve is to be fitted in the ballast suction to the cargo oil pump and a screw-down valve is to be fitted to the cargo oil lines.

5.3.4.5 Where the clean ballast pumps are installed in a cargo pump room, the sea inlets of these pumps are to be entirely separated from the sea inlets of the cargo pumps.

5.3.4.6 Water supply of fire main may be used as dynamic water of eductors for discharging ballast water of ballast tank or for discharging bilge water of cofferdam in cargo area, and following requirements are to be complied with:

(1) eductors are to be located in cargo area such as pump tank;

(2) water supply pipes from fire main for the above-mentioned purpose are to be led from upper deck in cargo hold area;

(3) a stop-check valve is to be fitted at appropriate position near deck before the water supply pipe passes through deck.

### 5.3.5 Air and sounding pipes for cofferdams

5.3.5.1 Deep cofferdams at the fore and aft ends of the cargo spaces and other tanks or cofferdams within the range of the cargo tanks, which are not intended for cargo, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with renewable wire gauze diaphragms at their outlets. The height of air pipes from the deck to the point where water may have access below is not to be less than 760 mm.

5.3.5.2 So far as practicable, the air and sounding pipes required in 5.3.5.1 are not to pass through cargo tanks. Were side ballast tank or empty side tank are not provided on ship, the air and sounding pipes in way of the double bottom may pass through cargo tanks. However a wall thickness of the pipes passing through cargo tanks are to comply with the requirements in Table 5.3.4.2 of this Chapter and such pipes are to be completion or with welded joints.

### 5.3.6 Location and separation of spaces in combination carriers

5.3.6.1 The slop tanks are to be surrounded by cofferdams except where the boundaries of the slop tanks where slop may be carried on dry cargo voyages are the hull, main cargo deck, cargo pump-room bulkhead or fuel oil tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump-room or other enclosed space. Means are to be provided for filling the

cofferdams with water and for draining them.
5.3.6.2 Means are to be provided for isolating the piping connecting the pump-room with the slop tanks referred to in 5.3.6.1. The means of isolation are to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump-room directly after the piping penetrates the bulkhead. A separate pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly over the open deck when the ship is in the dry cargo mode.
5.3.6.3 Hatches and tank cleaning openings to slop tanks are only permitted on the open deck and are to be fitted with closing arrangements. Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.
5.3.6.4 Where cargo wing tanks are provided, cargo oil lines below deck are to be installed inside these tanks. Where cargo wing tanks are not provided, cargo oil lines below deck are to be placed in special ducts which are capable of being adequately cleaned and ventilated.

# Section 4 CARGO OIL HEATING

### 5.4.1 General requirements
5.4.1.1 The medium used for heating cargo oil is to have a temperature not exceeding 220℃.

### 5.4.2 Steam heating
5.4.2.1 The steam used for heating cargo oil is to be of saturated steam.
5.4.2.2 An observation tank is to be provided for the heating coil drains and is to be located in a well ventilated and well illuminated part of the machinery space remote from the boilers, diesel engine exhaust pipes and electrical equipment. The upper drain pipe of the tank is to be led to a sludge tank.
5.4.2.3 The heating steam supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and these lines are to be run above the weather deck.
5.4.2.4 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank. The heating coil exhaust pipes of the cargo oil heating systems for each tank are to be fitted with inspection valves or cocks on the open deck to check the heating coils for leakage.
5.4.2.5 Spectacle flanges or spool pipes are to be provided in the heating steam supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

### 5.4.3 Thermal oil heating
5.4.3.1 Thermal oil heating of cargo oil is to comply with the relevant requirements of Section 8, Chapter 4 of this PART.
5.4.3.2 The heating oil supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank.
5.4.3.3 Isolating shut-off valves are to be provided at the inlet and outlet connections to the heating oil circuit(s) of each tank.
5.4.3.4 Spectacle flanges or spool pipes are to be provided in the heating oil supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks.

# Section 5 CARGO TANK LEVEL SOUNDING

### 5.5.1 General requirements
5.5.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level and following requirements respectively in 5.5.2 to 5.5.4 are to be complied with.

### 5.5.2 Closed sounding devices

5.5.2.1 In oil tankers fitted with a fixed inert gas system, the cargo tanks are to be fitted with closed sounding devices which do not permit the escape of cargo to the atmosphere when being used.

### 5.5.3 Limited sounding devices

5.5.3.1 Sounding pipes or other approved devices, which may permit a limited amount of vapor to escape to atmosphere when being used, would be accepted for those tanks which are not required to be fitted with closed sounding devices. The devices are to be so designed as to minimize the sudden release of vapor or liquid under pressure and the possibility of liquid spillage on deck. Means are also to be provided for relieving tank pressure before the device is operated. Arrangements which permit the escape of vapor to the atmosphere are not to be fitted in enclosed spaces.

### 5.5.4 Open sounding devices

5.5.4.1 Separate ullage openings may be fitted as a reserve means for sounding cargo tanks.

## Section 6 CARGO TANK VENTING ARRANGEMENTS

### 5.6.1 General requirements

5.6.1.1 Each cargo tank is to be fitted with venting arrangements which will limit the pressure or vacuum in the tanks. Vent pipes of cargo tanks are not to be in connection with the air pipes led from other tanks. Cargo tank venting arrangements are to be designed to provide:

(1) venting of large volumes of vapor/air mixtures during cargo handling and gas freeing operation;

(2) pressure/vacuum release of small volumes of vapor/air mixtures flowing during a normal voyage due to the change of temperature;

(3) a secondary means of allowing full flow relief of vapors, air or inert gas mixtures is to be provided in the event of failure of the arrangements in (1). The secondary means are to be capable of preventing over-pressure or under-pressure in the event of damage to, or inadvertent closing of, the means of isolation required in the paragraph 5.6.2.2 of the Section. Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in 5.6.1.1 (1), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

### 5.6.2 Pressure/vacuum and venting systems

5.6.2.1 The pressure/vacuum system and venting system may be separate or combined and may be connected to an inert gas system.

5.6.2.2 The vent and/or pressure/vacuum valve stand pipes are to be connected to the highest part of each tank, and where combined systems are adopted, a means of isolation is to be provided between each tank and a common main. Any means of isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with the provisions of 5.6.1.1(2). If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group are to be fitted with a means for over-pressure or under-pressure protection as required in 5.6.1.1(3) of this Section. Any isolation is also to continue to permit the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

5.6.2.3 In no case are shut-off valves to be fitted either above or in the pipe leading to a pressure/vacuum valves. However, by-pass valves may be fitted or provision may be made to enable the tank pressure/vacuum valves to be held in an open position. The arrangements are to be such that clear indication is given when the by-pass valve is open or the pressure/vacuum valve is secured in the open position.

5.6.2.4 The pressure/vacuum valve is to be located on open deck and means are to be provided to enable the functioning of the valve to be easily checked.

5.6.2.5 Pressure/vacuum valves are to be capable of preventing the cargo tanks from sustaining a positive pressure (generally not more than 0.021 MPa) which is greater than the testing pressure, and a negative pressure of less than 0.007 MPa.
5.6.2.6 The area of the venting system used during cargo loading is to be based on the maximum design loading rate and a gas evolution factor of 1.25.
5.6.2.7 Suitable drainage arrangements are to be provided in the vapor lines where condensate might collect.

### 5.6.3 Arrangement of vapor outlets

5.6.3.1 Outlets from vent pipes and, where necessary, outlets/inlets from pressure/vacuum valves are to be provided with readily renewable wire gauze[1]. Material of wire gauze is to be resistant to corrosion.
5.6.3.2 Vent outlets and pressure/vacuum valve, if used during loading, are to be arranged to discharge the vapor in an upward vertical direction. Vent outlets and pressure/vacuum valve inlets and outlets are to be arranged to prevent the entrance of water into the cargo tanks.

### 5.6.4 Height and location of cargo tank vent outlets

5.6.4.1 Vent outlets for cargo loading, discharging and ballasting required in 5.6.1.1(1) of this Section are to:
(1) permit the free flow of vapor mixtures; or
(2) permit the throttling of the discharge of the vapor mixtures to achieve a velocity of not less than 30 m/s.
They are also to be so arranged that the vapor mixture is discharged vertically upwards. Where the method is by free flow of vapor mixtures, the arrangement is to be such that the outlet is not to be less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.
Where the method is by high-velocity discharge, the outlets are to be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.
5.6.4.2 Openings for pressure release required in 5.6.1.1(2) of this Section are to be arranged in accordance with 5.6.4.1 of this Section.

### 5.6.5 Preventive measures against liquid rising in the venting system

5.6.5.1 Provisions are to be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This may be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and cargo tank filling procedures. For the purposes of this regulation, spill valves are not considered equivalent to an overflow system.

## Section 7 REQUIREMENTS FOR DOUBLE HULL SPACES OF OIL TANKERS

### 5.7.1 Inerting, ventilation and gas measurement of double hull spaces

5.7.1.1 Double hull spaces are to be provided with suitable ventilation connections.
5.7.1.2 On tankers required to be fitted with inert gas systems:
(1) double hull spaces are to be fitted with suitable connections for the supply of inert gas;
(2) where such spaces are connected to an inert gas distribution system, means is to be provided to prevent flammable gases from the cargo tanks entering the double hull spaces through the system;

[1] Refer to MSC/Circ.677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers and MSC/Circ.450/Rev.1 – Revised Factors to be Taken into Consideration when Designing Cargo Tank Venting and Gas Freeing Arrangements.

(3) where such are not connected to an inert gas distribution system, appropriate means is to be provided to allow connection to the inert gas main.

5.7.1.3 Tankers are to be provided with suitable portable instruments for measuring oxygen and flammable vapor concentrations. In selecting these instruments, due attention is to be given for their use in combination with the gas sampling systems referred to in 5.7.1.4 of this Section.

5.7.1.4 Where atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems is to be adapted to the design of such spaces.

5.7.1.5 The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastic materials are used, they are to be electrically conductive.

# Section 8 REQUIREMENTS FOR OIL TANKERS INTENDED FOR CARRIAGE OF CARGO OIL HAVING A FLASH POINT EXCEEDING 60℃

### 5.8.1 General requirements

5.8.1.1 For oil tankers intended for the carriage of cargo oil having a flash point above 60℃ (closed cup test) and where the maximum temperature heated for the cargo oil in cargo oil tanks is at least 10℃ below the flash point of the cargo oil, the requirements of this Chapter are to be complied with, but the following in this Chapter may not be applicable:

5.1.2, 5.1.4, 5.1.6, 5.1.8, 5.2.2.1 to 5.2.2.5, 5.2.3.1, 5.2.3.12, 5.2.4.5, 5.3.1.5, 5.3.3.1, 5.3.4.1, 5.3.4.6, 5.5.2.1, 5.6.1 to 5.6.5 and 5.7.1.

### 5.8.2 Vent pipes of cargo tanks

5.8.2.1 Vent pipes are to be led from the highest part of the tank to the open area above the freeboard deck and such pipes are not to be connected to those of other than cargo oil tank spaces.

5.8.2.2 Vent pipes required in 5.8.2.1 of this Section may be fitted for each cargo oil tank, vent pipes required for several cargo oil tanks may also be led to a common main, but it is proposed that a pressure/vacuum valves is to be fitted on the common main.

5.8.2.3 The height of the outlet ends of vent pipes (including branch and main) are not to be less than 760 mm above the freeboard deck.

5.8.2.4 The outlet ends of vent pipes are to be provided with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.

# CHAPTER 6 BOILERS AND PRESSURE VESSELS

Boilers and pressure vessels are to comply with the provisions in Chapter 6, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# CHAPTER 7 STEAM TURBINES

Steam turbines are to comply with the provisions in Chapter 7, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# CHAPTER 8 GAS TURBINES

Gas turbines are to comply with the provisions in Chapter 8, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# CHAPTER 9 DIESEL ENGINES

Diesel engines are to comply with the provisions in Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# CHAPTER 10 TRANSMISSION GEARING

Transmission gearing is to comply with the provisions in Chapter 10, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# CHAPTER 11 SHAFTING AND PROPELLERS

## Section 1 GENERAL PROVISIONS

### 11.1.1 Application

11.1.1.1 This Chapter is applicable to the shafting of ships propelled by diesel engines, steam turbines, gas turbines or electric propelling motors.

### 11.1.2 General requirements

11.1.2.1 Where the couplings are separate from the thrust shafts, intermediate shafts, tube shafts (i.e. the shaft which passes through the stern tube, but does not carry the propeller) and screwshafts, provision is to be made for the couplings to resist the astern pull so that no axial displacements of the couplings relative to the shafts may occur. Excessive stress concentration on the shafts is to be avoided.

11.1.2.2 Materials for shafting and propellers are to comply with the relevant requirements of CCS Rules for Materials and Welding.

The specified tensile strength of forgings for shafts is to be selected within the following general limits:

(1) for carbon and manganese steel, 400 ~ 760 $N/mm^2$. Where shafts may experience vibration stresses exceeding 90% permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength of 500 $N/mm^2$;

(2) for alloy steel, not exceeding 800 $N/mm^2$.

If the specified tensile strength exceeds the limitation value in 11.1.2.2(1) and (2) of this Chapter, calculation of shaft diameter is to comply with the provisions in 11.2.2.1 of this Chapter and calculation of permissible vibration stress is to comply with the provisions in 12.2.3.3, Chapter 12 of this PART.

For shaft couplings, nodular graphite cast iron may also be accepted.

11.1.2.3 The main propulsion shafting together with its transmission gears are to be capable of withstanding sufficient astern power.

For the main propulsion shafting with reduction gears, controllable pitch propellers or electric propelling motors, running astern are not to lead to the overload of main engines.

11.1.2.4 The sliding bearing temperature in the main propulsion shafting and transmission gearing is not to exceed 70°C , and not to exceed 80°C if roller bearing is fitted.

11.1.2.5 Alternative calculation methods may be considered by CCS. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given in Section 2 of Chapter 11 and Section 2 of Chapter 12.

### 11.1.3 Vibration and Alignment of Shafting

11.1.3.1 The shafting is also to comply with the requirements for shafting vibration and alignment in Chapter 12 of this PART.

### 11.1.4 Plans and documents

11.1.4.1 The following plans and documents of shafting and propellers are to be submitted for approval:

(1) Arrangement of Shafting;

(2) Thrust shaft, intermediate shaft, tube shaft (where applicable), and screwshaft;

(3) General arrangement of stern tube, including oil sealing gland and tube shaft bearings;

(4) Strength calculations for shafting, including calculations for the connection of couplings and strength calculations of bolts;

(5) Strength calculations for propellers;

(6) Propeller (including the clearances between the propeller and hull etc.);

(7) Oil shrink fitting of key or keyless propeller together with calculations (where applicable).

11.1.4.2 Detailed sizes and necessary parameters for verifying the calculations are to be indicated in plans.

# Section 2 SHAFTING

### 11.2.1 General requirements

11.2.1.1 The minimum diameter of shafts determined by the formulae in this Section is to be checked for the allowable torsional vibration stress as specified in Chapter 12 of this PART.

### 11.2.2 Diameter of shafts

11.2.2.1 Low cycle fatigue criterion (typically < $10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable.

The shaft diameter d is not to be less than the value determined by the following formula:

$$d = FC \sqrt[3]{\frac{N_e}{n_e}\left(\frac{560}{R_m + 160}\right)} \quad \text{mm}$$

where: $F$ — factor for the type of propulsion installation:

$F$= 95 for intermediate shafts in turbine installations, diesel installations with hydraulic (slip type) couplings, electric propulsion installation;

$F$= 100 for all other diesel installations and all propeller shafts;

$C$ — factor for the particular shaft design features (see Table 11.2.2.1) or calculated in accordance with the following formula;

$$C = \left[\frac{scf}{1.45}\right]^x$$

$x$ — low cycle notch sensitivity. The chosen values are mainly representative for soft steels ( $R_m$ < 600), while the influence of steep stress gradients in combination with high strength steels may be underestimated;

$scf$ — the stress concentration factors relative to the stress concentration for a flange with fillet radius of 0.08d (geometric stress concentration of approximately 1.45);

$N_e$ — rated power transmitted through the shaft, in kW;

$n_e$ — speed in revolution per minute of shaft at rated power, in r/min;

$R_m$ — specified tensile strength of shaft material, in N/mm$^2$. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 760 N/mm$^2$ for $R_m$> 760 N/mm$^2$; when alloy steel is used, it is to be taken as 800 N/mm$^2$ for $R_m$> 800 N/mm$^2$. For special approval of alloy steel used for intermediate shaft material, the tensile strength of shaft material may be greater than 800 N/mm$^2$, but less than 950 N/mm$^2$, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness② and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of CCS Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm$^2$ for $R_m$> 600 N/mm$^2$.

**Factor *C* for different design features** **Table 11.2.2.1**

| Intermediate shafts with | Thrust shafts external to engines | Propeller shafts |
|---|---|---|

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

| Integral coupling flange | Keyless couplings fitted by oil shrink method | keyway | Radial hole | Longitudinal slot | The portion of thrust shafts outside the thrust collar at a length equal to the thrust shaft diameter, the remainder may be tapered down to the diameter required for the intermediate shaft | In way of axial bearings where roller bearing is used as thrust bearing | Flange mounted or keyless taper fitted propeller shafts | Key fitted propeller shafts | The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead |
|---|---|---|---|---|---|---|---|---|---|
| 1.0[①] | 1.0[⑦] | 1.10[②⑤⑧] | 1.10[③⑤] | 1.20[④⑤] | 1.10 | 1.10 | 1.22 | 1.26 | 1.15 |

Notes:

① The fillet radius at the base of the flange is not to be less than 0.08*d*.

② For over a length of at least 0.2*d* of the shaft from the ends of keyway and, the diameter of the shaft is to be increased by taking $C$ = 1.10. The diameter of the shaft is to be decreased by taking $C$ = 1.0 for the range beyond. The fillet radius in the transverse section at the bottom of the keyway are not to be less than 0.0125*d*.

③ For over a length of at least 0.2*d* of the shaft from the ends of hole and, the diameter of the shaft is to be increased by taking $C$ = 1.10. The diameter of the shaft is to be decreased by taking $C$ = 1.0 for the range beyond. The diameter of the hole is not to be greater than 0.3*d*. The intersection between a radial and an eccentric axial bore is not applicable, as shown in the figure below.

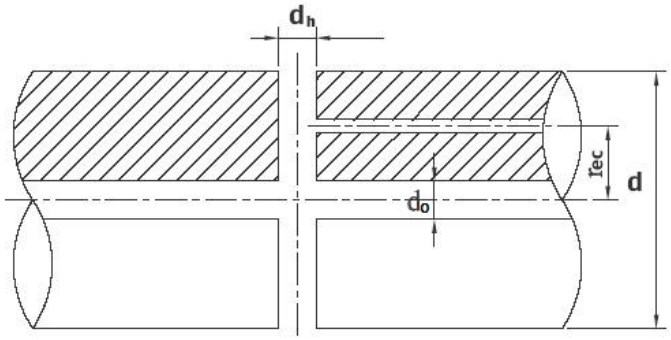



**Figure 11.2.2.1 Intersection Between a Radial and an Eccentric Axial Bore**

④ For over a length of at least 0.3*d* of the shaft from the longitudinal slot and its ends, the diameter of the shaft is to be increased by taking $C$ = 1.20. The diameter of the shaft is to be decreased by taking $C$ = 1.0 for the range beyond. In general, slot length is to be less than 0.8*d*, width is to be more than 0.15*d* and inner diameter is to be less than 0.7*d*. The end rounding of the slot is not to be less than half of the slot width and the quantity of slot is not to be more than 3. Slots at respectively 180º apart for 2 slots, and slots at respectively 120º apart for 3 slots. An edge rounding is preferably to be avoided as this increases the stress concentration slightly.

⑤ For shaft having several design features, the factor is to be the product of several factors.

⑥ Where, *d* is calculated with $C$ = 1.0.

⑦ Where shafts may experience vibratory stresses exceeding 90% the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2%.

⑧ Keyways are in general not to be used in installations with a barred speed range.

11.2.2.2 Screwshafts or tube shafts forward of the aft peak bulkhead may be gradually reduced to the diameter of the intermediate shaft.

11.2.2.3 The diameter of the screwshaft determined in accordance with the formula in 11.2.2.1 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2.5 times the diameter of the screwshaft, whichever is the greater.

11.2.2.4 Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

### 11.2.3 Hollow shaft diameter

11.2.3.1 For shafts where the bore $d_0$ is greater than 0.4*d*, the actual external diameter $d_a$ of the shaft is not to be less than that determined by the following formula:

$$d_a = d\sqrt[3]{\frac{1}{1-\left(\frac{d_0}{d_a}\right)^4}} \quad \text{mm}$$

where: $d$ — shaft diameter determined by 11.2.2.1 of this Section, in mm;
$d_0$— actual bore of the shaft, in mm.

11.2.3.2 The edges of slots and holes in the shafts are to be smooth and without any traces of machining.
11.2.3.3 For ships engaged only in harbor service, the minimum diameter of the shafts may be reduced by 3%.

**11.2.4 Shaft liners**
11.2.4.1 The thickness $t$ of bronze shaft liners shrunk on tube shafts or screwshafts, in way of the bushes, is not to be less than:

$$t = 0.03d + 7.5 \quad \text{mm}$$

where: $d$ – diameter of tube shaft or screwshaft in way of the bushes, in mm.
The thickness of stainless steel liners, where fitted, is to be one-half that obtained above, but not less than 6 mm.
11.2.4.2 The thickness of a continuous liner between the bushes may be somewhat reduced, but is not to be less than 0.75$t$.
11.2.4.3 Continuous liners are to be generally cast in one piece. Where necessary, they may consist of two or more pieces, but these are to be butt-welded by reliable methods to prevent water ingress. .
11.2.4.4 Where the portion of the shaft between any two lengths of the liner is protected with glass-reinforced plastics or other industrial plastics, the protection at the junction of the liner ends is to be of such a construction as to prevent the shaft from water ingress. In general, semicircular groove may be at the junction of the liner ends which is protected with several layers of glass-reinforced plastics or other industrial plastics and secured with copper wire or stainless steel wire. The connection portions are not to be located within the bearing range.
11.2.4.5 Shaft liners which are cast in one piece or consist of two or more lengths, are to be subject to hydraulic test to a pressure of 0.2 MPa after rough machining, and there is to be no crack or leakage.
11.2.4.6 Liners are to be carefully shrunk on, or forced on, to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.
11.2.4.7 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

**11.2.5 Stern tubes and bearings**
11.2.5.1 The length of the bearing in the stern bush next to and supporting the propellers is to be as follows:
(1) For water lubricated bearings, the length of the bearing is not to be less than 4 times the rule calculated diameter for the screwshaft in way of the bearing. For water lubricated synthetic materials, if the design and materials of bearings comply with CCS provisions as demonstrated by tests, the length of the bearings may be appropriately reduced, but not less than 2 times the rule diameter of the shaft in way of the bearing. Synthetic materials of water lubricated stern tube bearings are to be type approved.
(2) For bearings which are white-metal lined and oil lubricated, the length of the bearing is not to be less than twice the rule calculated diameter for the screwshaft in way of the bearing. If the normal bearing pressure is less than 0.8 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is to be not less than 1.5 times the actual diameter.
(3) For bearings of synthetic rubber, reinforced resin or plastics materials which are approved for use as oil lubricated stern bush bearings, the length of the bearing is to be not less than twice the rule diameter of the shaft in way of the bearing. If the normal bearing pressure is less than 0.6 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is

to be not less than 1.5 times the actual diameter. Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.
Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.
(4) The length of a grease lubricated bearing is to be not less than 4.0 times the rule diameter of the shaft in way of the bearing.
(5) For bearings which are lined with other materials or lubricated by other methods, background for adopting its bearing length is to be provided, e.g. test results such as expansion characteristics and bearing capability of bearing material or service experience.
11.2.5.2 Forced water lubrication is to be provided for all bearings lined with rubber or plastics and for those lined with lignum vitae where the shaft diameter is 400 mm or over. A shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the stern tube where the water supply enters the stern tube forward of the bulkhead.
11.2.5.3 Bearings which are oil lubricated are to be fitted with an approved oil sealing gland.
11.2.5.4 Where a gravity tank supplying lubricating oil to the stern bush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.
11.2.5.5 Where stern bush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the stern tube or by other suitable means.
11.2.5.6 Stern tubes are to be subject to hydraulic test to a pressure of 0.2 MPa before being fitted on board ship.
11.2.5.7 When rolling bearings are used for bearings adjacent to and supporting propellers, the service life of rolling bearing are to be calculated in accordance with ISO 281 or other recognized standards. The calculated service life is to comply with the requirements for overhaul period. Ships using rolling bearings are generally non-passenger ships engaged in coastal voyages with dual propulsion systems. The selected rolling bearings are in general to have self-aligning function. The number, installation and service condition of rolling bearings are to be agreed by CCS.

# Section 3 SHAFT TRANSMISSION UNITS

### 11.3.1 Application

11.3.1.1 The requirements of this Section apply to couplings, hydraulic transmission arrangements, clutches, Z propulsion arrangement, transverse propulsion arrangement (if applying for additional notation) as well as controllable pitch propeller blade actuators. For transmission gearing, see Chapter 10 of this PART.

### 11.3.2 Couplings

11.3.2.1 Flange couplings are to comply with the following requirements:
(1) The thickness of coupling flanges is not to be less than 20% of the intermediate shaft diameter required in 11.2.2.1, nor is it to be less than the diameter of the fitting coupling bolts whose minimum tensile strength is equivalent to that of the shafts. The fillet radius at the base of flange is not to be less than 8% of the diameter of the shaft connecting the coupling. Special consideration will be given for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.
(2) Where the propeller is attached to the screwshaft by means of a coupling flange, the thickness of the flange is not to be less than 25% of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of coupling flange is not to be less than 12.5% of the actual diameter of the shaft at the coupling.
(3) Fillets are to have a smooth finish and not to be recessed in way of nuts and bolt heads. The fillet may be formed of multiradii in such a way that the stress concentration factor is not to be greater than that for a circular fillet with radius 0.08 times the actual shaft diameter.
11.3.2.2 Where the coupling is fitted to the shaft with a key and the torque is transmitted through the key, the effective sectional area of the key in shear is not to be less than that determined by the following formula, and the tensile strength of the key material is to be equal to or greater than that of the shaft material:

$$BL \geqslant \frac{d^3}{2.6 d_m} \quad \text{mm}^2$$

where: $B$ – breadth of key, in mm;
$L$ – effective length of key, in mm;
$d$ – diameter of intermediate shaft determined in 11.2.2.1 of this Chapter, in mm;
$d_m$ – diameter of shaft at mid-length of the key, in mm.

11.3.2.3 Keyless couplings fitted by oil shrink method are to meet the following requirements:
(1) Muff couplings are to have a capacity of transmitting a torque which is 2.8 times the mean torque and their equivalent stress of the maximum shrinkage allowance is not to be more than 70% of the yield stress of the muff material.
(2) For general couplings which are not covered in (1) above, the pull-up $S$ or shrinkage allowance $\delta$ is to meet the following requirements:

$$S_1 \leqslant S \leqslant S_2 \quad \text{mm}$$

$$\delta_1 \leqslant \delta \leqslant \delta_2 \quad \text{mm}$$

$$S_1 = \frac{\delta_1}{K} = \frac{1}{K}\left[\frac{1672 N_e}{A n_e}(c_1 + c_2) + 0.03\right] \quad \text{mm}$$

$$S_2 = \frac{\delta_2}{K} = \frac{0.034 \times 10^{-4}}{K} R_{eH} d_1 (c_1 + c_2) \frac{K_2^2 - 1}{\sqrt{3K_2^4 + 1}} \quad \text{mm}$$

where: $S_1$ – minimum axial pull-up, in mm;
$S_2$ – maximum axial pull-up, in mm;
$\delta_1$ – minimum shrinkage allowance, in mm;
$\delta_2$ – maximum shrinkage allowance, in mm;
$K$ – taper of the shaft for shrink-fit;
$N_e$ – rated power transmitted by the shaft, in kW;
$n_e$ – speed of the shaft at $N_e$, in r/min;
$A$ – theoretical contact area of the shrinkage surface, in mm$^2$;

$$c_1 = \frac{1 + K_1^2}{1 - K_1^2} - \mu_1;$$

$$c_2 = \frac{K_2^2 + 1}{K_2^2 - 1} + \mu_2;$$

$$K_1 = \frac{d_0}{d_1};$$

$$K_2 = \frac{d_2}{d_1};$$

where: $d_0$ – bore diameter of the shaft, in mm;
$d_1$ – mean diameter of the shaft within the contact length, in mm;
$d_2$ – mean outside diameter of the coupling within the contact length, in mm;
$\mu_1 = \mu_2 = 0.3$;
$R_{eH}$ – specified yield stress of the coupling material, in N/mm$^2$.

11.3.2.4 Clamp couplings are to meet the following requirements:
(1) Clamp couplings are to have a strength at least equal to the required strength of the intermediate shaft.
(2) The clamp coupling is to be provided with a key. For couplings transmitting thrust, a satisfactory axial locking device is to be provided.
(3) Torque is to be transmitted by the frictional moment resulting from clamping and the key. The frictional moment is not to be less than the rated torque to prevent track slip and the sizes of the

key are not to be less than 2/3 of those determined by the formula in 11.3.2.2.
(4) The clamping length of the coupling is normally to be at least 2.4 times shaft diameter.
11.3.2.5 Where other types of couplings or connections are used for torque transmission, background of test results or service experience are to be provided for the purpose of examining their reliability.

### 11.3.3 Coupling bolts

11.3.3.1 For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter $d_f$ is not to be less than that given by the following formula:

$$d_f = 0.65\sqrt{\frac{d^3(R_m + 160)}{DZR_{mb}}} \quad \text{mm}$$

where: $d$ – Rule diameter of the solid intermediate shaft, in mm, in accordance with the requirements of Chapter 14 of this PART, taking into account ice strengthening requirements where applicable;
$Z$ – number of bolts;
$D$ – pitch circle diameter, in mm;
$R_m$ – tensile strength of the intermediate shaft material for calculation, in N/mm$^2$;
$R_{mb}$ – tensile strength of the fitted coupling bolts material taken for calculation, in N/mm$^2$, where: $R_m \le R_{mb} \le 1.7\ R_m$, but not higher than 1,000 N/mm$^2$.

11.3.3.2 Where it is proposed to use non-fitting bolts for connections, the diameter $d_n$ at the root of thread of the bolts is not to be less than that determined by the following formula:

$$d_n = 25\sqrt{\frac{N_e \times 10^6}{n_e DZR_{mb}}} \quad \text{mm}$$

where: $N_e$ – rated output transmitted by the shaft, in kW;
$n_e$– speed of the shaft at $N_e$, in r/min;
other symbols are as defined in 11.3.3.1 of this Section.
The prestressing force and workmanship of ordinary bolts are to be provided for information.
11.3.3.3 Bolts connecting propellers and screwshafts are to be fitting bolts, the diameter of which is to be increased by 5% of that determined in 11.3.3.1 of this Section.
11.3.3.4 For ships engaged only in harbor service, the diameter of the connecting bolts may be reduced by 4%.
11.3.3.5 The diameter of the fitting bolts at the joining faces of the couplings within the crankshaft and thrust shaft/crankshaft is to be increased by 5% of that determined by 11.3.3.1 of this Section.

### 11.3.4 Clutches and control devices

11.3.4.1 The friction elements of clutches for reversible gearing are not to give any slip in normal running. While the clutch is disengaged, the propulsion shafting is not to be dragged along by the driving shaft.
11.3.4.2 The maximum torque transmitted by the clutch is, in general, not to be less than 1.5 times the rated torque of the main engine.
11.3.4.3 The flexible clutches controlled by air pressure are to be provided with air charging pressure gauges, signal devices for indicating clutching and declutching of the clutches and alarm devices for giving warning of high and low air pressures.
11.3.4.4 An emergency device for air charging is to be fitted to the system which supplies air to the pneumatic flexible clutch.
11.3.4.5 For reversible clutches, the time required for reversal is not to be more than 15 s.
11.3.4.6 In single screw ships having clutches, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of the clutches.

### 11.3.5 Hydraulic transmissions

11.3.5.1 In single screw ships having emergency mechanical means are to be provided to ensure

that the ship can run at a reasonable speed in the event of failure of the hydraulic transmission systems.

11.3.5.2 The lubricating oil system of hydraulic transmission arrangements is to be separate from other systems. The system is to consist of filters, coolers, drain tanks, etc. In the case of hydraulic gear transmission, in addition, magnetic filters are to be provided in the system.

11.3.5.3 Hydraulic transmission arrangements are to be provided with separate stand-by pumps. For propulsion systems with twin-engine and twin-screw, one stand-by pump may be accepted.

11.3.5.4 In addition to thermometers and pressure gauges, the lubricating oil system of hydraulic transmission arrangements is to be fitted with alarm devices for giving warnings of an excessive temperature and appreciable reduction in pressure of the oil supply.

11.3.5.5 The runners and impellers of hydraulic couplings are to be statically balanced. Furthermore, it is recommended that the runners and impellers be dynamically balanced.

11.3.5.6 Signal devices for indicating oil charging and discharging are to be fitted at the control positions of hydraulic transmission arrangement.

11.3.5.7 The hydraulic transmission arrangements may be controlled at the engine side and in the centralized control station or in the bridge. Where two or more control devices are fitted, they are to be interlocked one another.

11.3.5.8 In the case of multiple engines operating on one screwshaft, an interlocking device is to be provided in the control gear of the hydraulic transmission arrangement to prevent them from being filled with oil when the engines are in opposite directions.

11.3.5.9 At the centralized control station of hydraulic transmission, a tachometer showing the speed of the screwshaft and an indicator showing the direction of its rotation are to be fitted.

### 11.3.6 Transmission devices for controllable pitch propeller

11.3.6.1 The hydraulic transmission system of controllable pitch propeller blade actuators is to be provided with a separate stand-by pump having a capacity of not less than that required for power hydraulic oil pump during normal operation of one hydraulic transmission system of controllable pitch propeller. One independent stand-by pump may be common to hydraulic transmission system of controllable pitch propeller of duplicated propulsion shafting system. Where each hydraulic transmission system of controllable pitch propeller is provided with independent hydraulic pump, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.

For propulsion plants up to 200 kW, one power-driven pump set is sufficient provided that, in addition, a hand-operated pump is fitted for controlling the blade pitch and that this enables the blades to be moved from the ahead to the astern position in a short enough time.

11.3.6.2 Pitch angle indicators are to be fitted both at the engine room control station and in the bridge. The deviation from the actual pitch angle is not to exceed ±1°.

11.3.6.3 The control system in the engine room is to be interlocked with that in the bridge. For control systems other than those actuated by mechanical devices, a stand-by manual control is to be fitted at the engine side.

11.3.6.4 The control system of hydraulic controllable pitch propeller blade actuators is to be such that the blade pitch can be altered efficiently and accurately.

11.3.6.5 Under any working conditions, the blade position of controllable pitch propellers is to be stable. Its fluctuation at 0° pitch angle is not to exceed ±0.5°.

11.3.6.6 At the rated speed of the propeller, the time required for the change of pitch angle from 1/3 positive maximum (or 1/3 negative maximum) to 1/3 negative maximum (or 1/3 positive maximum) is not to exceed 15 s.

11.3.6.7 The pitch adjusting range of controllable pitch propeller is to ensure that the main engine will provide rated power under rated speed and specified astern power.

11.3.6.8 Thread core diameter $d_k$ of blade fastening bolts is not to be less than the value obtained from following formula:

$$d_k = 2.6\sqrt{\frac{W_{0.35R} R_{P0.2} \alpha_A}{dZR_{eH}}} \quad \text{mm}$$

where: $W_{0.35R}$ — section modulus of cylindrical section at radius 0.35$R$, in mm$^3$;

$$W_{0.35R} = 0.11\,(Bt^2)_{0.35R}$$

where: $B$ — breadth of blade on section at radius 0.35$R$, in mm;

$t$ — maximum thickness of blade on section at radius 0.35$R$, in mm.

$R_{P0.2}$ — 0.2% proof stress of propeller material, in N/mm$^2$;

$\alpha_A$ — tightening factor for retaining bolts, = 1.2 to 1.6, depending on the method of tightening used;

$d$ — diameter of pitch circle of bolt hole of fastening bolts, in mm;

$Z$ — number of bolts;

$R_{eH}$ — yield strength of fastening bolts, in N/mm$^2$.

11.3.6.9 Under following conditions, the controllable pitch propeller is to have alarm function:

(1) pressure of hydraulic system is too low;

(2) oil level of main hydraulic oil tank is too low;

(3) oil filter is blocked;

(4) pressure of boss lubricating oil is too low (except for grease lubricating method);

(5) temperature of hydraulic oil is too high;

(6) pitch adjusting function fails;

(7) power supply of control system fails.

11.3.6.10 Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

11.3.6.11 Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades does not change or assumes a final position slowly enough to allow the emergency control system to be put into operation.

11.3.6.12 Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to remain in operation should the remote control system fail. It is recommended that a device be fitted which locks the propeller blades in the "ahead" setting.

In case of emergent fixed propeller condition, effective measures are to be provided to prevent pitch adjustment.

11.3.6.13 Before being installed on board, the pipe lines and pressure elements of hydraulic transmission system and control system for controllable pitch propellers are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, the system is to be tested to 1.25 times the working pressure for tightness, but need not exceed the design pressure plus 7 MPa.

11.3.6.14 Controllable pitch propeller and its main parts are to be subject to material test and non-destructive test according to the relevant requirements of CCS Rules for Materials and Welding.

11.3.6.15 A sealing is to be inserted between the propeller blade and the propeller boss to prevent the ingress of sea water and sand as well as the leakage of lubricating grease.

11.3.6.16 The inside of the propeller bosses is to be filled up with lubricating grease.

### 11.3.7 Z propulsion arrangement

11.3.7.1 Z propulsion arrangement is to be provided with means to control its propulsion direction from bridge, machinery control station (if any) and on the spot. Indicators of direction of thrust are to be provided in these control locations.

11.3.7.2 When the output shaft of main engine and input shaft of Z propulsion arrangement are not in the same level, universal couplings are to be provided in pair with same angle which is in general not to be more than 10°.

11.3.7.3 If Z propulsion arrangement has electric or electro-hydraulic power equipment of steering turning device , spare power equipment or other emergency control measures are to be provided.

If there are two or more Z propulsion arrangement on the ship, spare power equipment is not necessary.

11.3.7.4 The diameters of input shaft, vertical shaft and propeller shaft of Z propulsion arrangement are not to be less than the value obtained from calculation according to the formula in 11.2.2.1 of this Chapter.

11.3.7.5 Shafting vibration calculation of Z propulsion arrangement is to comply with the requirements in Chapter 12 of this PART.

11.3.7.6 Strength and installation of propeller of Z propulsion arrangement are to comply with

the requirements in Section 4, Chapter 11 of this PART.
11.3.7.7 All alarms related to system failure are to be shown on maneuvering console. Z propulsion arrangement is to have alarm function under following conditions:
(1) low pressure of lubricating oil;
(2) high temperature of lubricating oil;
(3) low level of hydraulic oil;
(4) low pressure of hydraulic oil;
(5) high temperature of hydraulic oil (if fitted with oil cooler);
(6) too high pressure difference of hydraulic oil filter (if fitted with oil filter);
(7) low pressure of clutch.
11.3.7.8 On completion of manufacture of parts of Z propulsion arrangements such as upper and lower gearbox, rotating rudder gearbox and rudder post, 0.2 MPa hydraulic test is to be carried out and tightness test is to be carried out after assembly. Tightness test may be carried out using liquid with 0.1 MPa pressure, and 0.03 MPa compressed air may be used for test examination by means of applying soap liquid. No leakage is permitted.
11.3.7.9 Hydraulic pipes are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, they are to be tested together with fittings to 1.25 times the design pressure for tightness.
11.3.7.10 Z propulsion arrangement together with its main parts and accessories are to be subject to material test and non-destructive test according to CCS Rules for Materials and Welding.
11.3.7.11 Steering gear of Z propulsion arrangement is to comply with the requirements of Section 1, Chapter 13, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

### 11.3.8 Transverse propulsion arrangement

11.3.8.1 Transverse propulsion arrangement is to have sufficient transverse thrust to satisfy the working requirements of navigation at low speed and docking and leaving wharf.
11.3.8.2 Material and test of transverse propulsion arrangement and its components are to comply with the relevant requirements of CCS Rules for Materials and Welding.
11.3.8.3 Diesel engines driving transverse propulsion arrangement are to comply with the relevant requirements in Chapter 9 of this PART.
11.3.8.4 Motor and distribution system of driving transverse propulsion arrangement are to comply with the relevant requirements in PART FOUR of the Rules.
11.3.8.5 The design of shafting together with its parts and propeller is to comply with the relevant requirements of this Chapter.
11.3.8.6 The thickness of tunnel of transverse propulsion arrangement is not to be less than the adjacent part of the hull.
11.3.8.7 The shaft sealing box is to be installed to prevent water so as to protect steel shafts from sea water.
11.3.8.8 Alarm is to be in the bridge with individual or groupwise indicator for the following faults:
(1) overload of prime mover and servo unit;
(2) power failure of remote control system;
(3) power failure of alarm system;
(4) low level in lubrication oil tank (if fitted);
(5) low lubrication oil pressure (if forced lubrication oil system);
(6) low level in hydraulic supply tank;
(7) low pressure in hydraulic system.
11.3.8.9 Individual indication in the bridge is required for:
(1) running and stop of prime mover;
(2) propeller pitch for controllable pitch propeller plants;
(3) direction of rotation and r.p.m. for fixed propeller plants.
11.3.8.10 It is to be possible to stop the transverse propulsion arrangement from the bridge by means of a system independent of the remote control system.

# Section 4 PROPELLERS

### 11.4.1 General requirements

11.4.1.1 Propellers are to be subject to surface inspection and size verification as well as to static balancing test. For built-up propellers and controllable pitch propellers, the static balancing test is to be carried out respectively after machining and assembling.

11.4.1.2 Blade fastening studs of built-up propellers are to be made of forged steel having a tensile strength not less than 400 N/mm$^2$.

11.4.1.3 Fasteners (studs, nuts, etc.) for propellers and for their accessories are to be fitted with reliable devices to prevent loosening and corrosion.

### 11.4.2 Clearances between propeller and hull

11.4.2.1 For the purpose of modifying the effect of propeller excitation on hull, the necessary minimum clearances between the propeller and the hull are to be provided as specified in 2.14.4 of PART TWO.

### 11.4.3 Thickness of propeller blades

11.4.3.1 The thickness of propeller blades $t$ (at 0.25$R$ and 0.6$R$ for solid propellers, and at 0.35$R$ and 0.6$R$ for controllable pitch propellers) is not to be less than that calculated by the following formula:

$$t = \sqrt{\frac{Y}{K - X}} \qquad \text{mm}$$

where: $Y$ – power coefficient, to be obtained from 11.4.3.2 of this Section;

$K$ – material coefficient given in Table 11.4.3.1;

$X$ – speed coefficient, to be obtained from 11.4.3.3 of this Section.

**Propeller material coefficient *K*** **Table 11.4.3.1**

| Material | tensile strength $R_m$ (N/mm$^2$) | Material density *G* (g/cm$^3$) | Material coefficient K |
|---|---|---|---|
| Carbon steel and alloy steel | 400 | 7.9 | 0.57 |
| Ferritic and martensitic stainless steel | 500 | 7.7 | 1.04 |
| Austenitic stainless steel | 450 | 7.9 | 1.04 |
| Cu1 manganese bronze | 440 | 8.3 | 1 |
| Cu2 nickel-manganese bronze | 440 | 8.3 | 1 |
| Cu3 nickel-aluminum bronze | 590 | 7.6 | 1.38 |
| Cu4 manganese-aluminum bronze | 630 | 7.5 | 1.17 |

Note: For materials other than specified in the above Table, the value *K* may be determined by making reference to those given in the Table.

11.4.3.2 Power coefficient *Y* is to be calculated by the following formula:

$$Y = \frac{1.36 A_1 N_e}{Z b n_e}$$

where:

$$A_1 = \frac{D}{P}(K_1 - K_2 \frac{D}{P_{0.7}}) + K_3 \frac{D}{P_{0.7}} - K_4;$$

*D* – propeller diameter, in m;

*P* – pitch at the section under consideration, in m;

$P_{0.7}$– pitch at 0.7 *R*, in m;

*R* – propeller radius, in m;

$K_1$, $K_2$, $K_3$, $K_4$–coefficients given in Table 11.4.3.2;

$N_e$– rated power of the main engine, in kW;

*Z* – number of blades;

*b* – blade width at the section under consideration, in m;

$n_e$– speed of the propeller at rated power of main engine, in r/min.

For aerofoil sections with trailing edge washback, the value of $A_1$ obtained from above formula is to be increased by 30%. The trailing edge washback is the offset of the trailing edge of the tangent plane of the propeller blade in respect to the pitch baseline (external chord) of the blade face, as shown in Figure 11.4.3.2, e.g. 0.6*R* without washback and 0.25*R* with washback.

**Coefficient *K* values in way of different diameters of propeller** **Table 11.4.3.2**

| *K* / *r* | $K_1$ | $K_2$ | $K_3$ | $K_4$ | $K_5$ | $K_6$ | $K_7$ | $K_8$ |
|---|---|---|---|---|---|---|---|---|
| 0.25*R* | 634 | 250 | 1410 | 4 | 82 | 34 | 41 | 380 |
| 0.35*R* | 520 | 285 | 1320 | 16 | 64 | 28 | 57 | 420 |
| 0.60*R* | 207 | 151 | 635 | 34 | 23 | 12 | 65 | 330 |

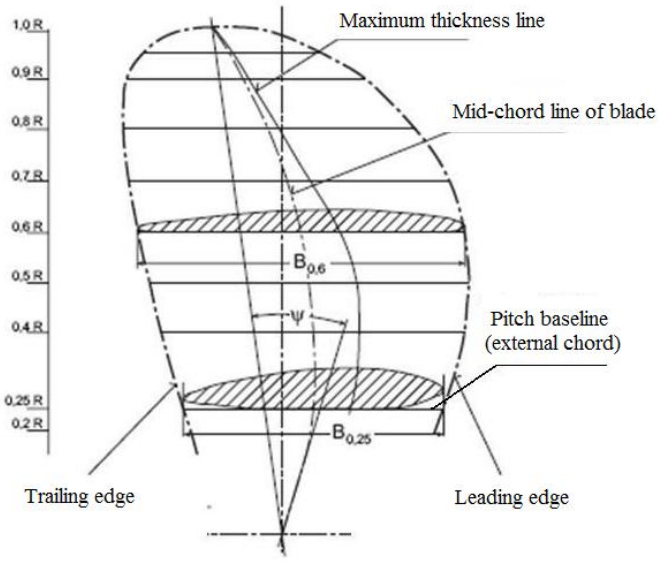



**Figure 11.4.3.2**

11.4.3.3 Speed coefficient $X$ is to be calculated by the following formula:

$$X = \frac{A_2 G A_d n_e^2 D^3}{10^{10} Zb}$$

where: $A_2 = \frac{D}{P}(K_5 + K_6\varepsilon) + K_7\varepsilon + K_8$

$D$, $P$, $n_e$, $Z$ and $b$ as defined in 11.4.3.2 of this Section;

$\varepsilon$ — rake angle of propeller blade, in degrees. The value of the rake angle is positive for backward rake and negative for forward rake. The rake angle is, as shown in the side view of propeller, is an angle taken in one of the following three conditions:

— $\varepsilon_1$ and $\varepsilon_2$ are backward rake angles: the more backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(1));

— $\varepsilon_1$ and $\varepsilon_2$ are forward rake angles: the less forward one is to be taken ($\varepsilon = \varepsilon_2$, as shown in Figure 11.4.3.3.3(2));

— $\varepsilon_1$ and $\varepsilon_2$ are rake angles on both sides of the centreline: the backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(3)).

$\varepsilon_1$ is the angle measured from the line perpendicular to shaft centerline to the tangent to the backward thickness line at the radius 0.6R of the side projection of propeller blade;

$\varepsilon_2$ is the angle obtained by the following formula:

$$\varepsilon_2 = \tan^{-1}\frac{e}{R}$$

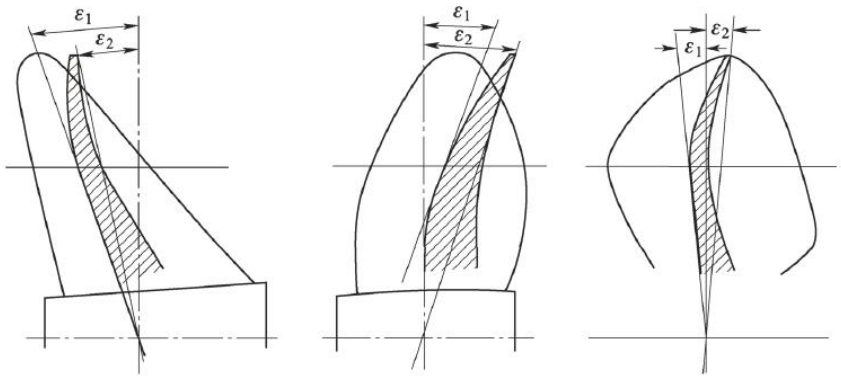
where: $e$ — rake (radial inclination of blade section forward or backward from the reference line, taken as the distance between the blade tip projected on the propeller shaft and the intersection of the reference line and the propeller axis), in m;

$R$ — the same as in 11.4.3.2.

$K_5$, $K_6$, $K_7$, $K_8$ — coefficients given in Table 11.4.3.2;

$G$ — density of the propeller material, in g/cm$^3$;

$A_d$ — expanded area ratio.




(1) (2) (3)

**Figure 11.4.3.3 Rake Angle of Propeller Blade**

11.4.3.4 The thickness of propeller blades is permitted to be calculated by some other appropriate methods, but background of test results or service experience is to be provided.

11.4.3.5 Depending on the condition of application of the propeller, detailed data of wake field in periphery of the propeller or blade thickness increase may be required. .

### 11.4.4 Fitting of propellers to screwshafts

11.4.4.1 Where it is proposed to fit the propeller to the screwshaft with a flange, the diameter of flange bolts is to comply with the requirements of 11.3.3.1 and 11.3.3.3 of this Chapter, and the thickness of flanges is to comply with the provisions of 11.3.2.1(2) of this Chapter.

11.4.4.2 Where it is proposed to fit the propeller to the screwshaft with a key, the propeller boss is to be a good fit on the screwshaft cone. The length of the forward fitting surface is to be about the diameter of the screwshaft.

The taper of the coned end of screwshaft is not to exceed 1/10, and for keyless propellers fitted by oil injection method, such taper is not to exceed 1/15.

The intersection of cylindrical and conical portions of screwshafts is not to be shouldered or rounded. The forward end of the keyway in the screwshaft is to be smoothed and sled-runner shaped. In general, the shape and size may be in accordance with Figure 11.4.4.2, where $r_1 < r_2 < r_3 < r_4$, $AB = BC = CD = DF = x$ ($x$ being depth of keyway).

For $r_1$, $r_2$, $r_3$ and $r_4$, refer to the following:

$r_1 = x/8$, $r_2 = 3x/8$, $r_3 = 3x/4$, $r_4 = x$.

The values of $r_5$ are given in Table 11.4.4.2.

The outside diameter of the threaded end for the propeller retaining nut is not to be less than 60% of the calculated major taper diameter.

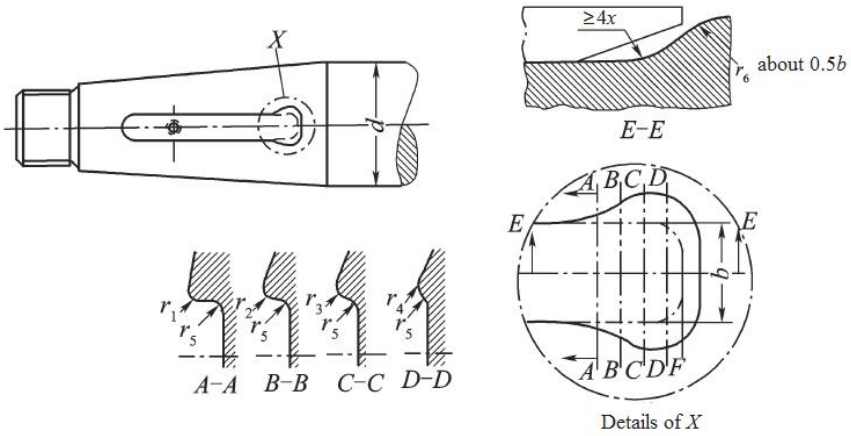



**Figure 11.4.4.2**

**Values of $r_5$** **Table 11.4.4.2**

| $d$ (mm) | $r_5$ (mm) |
|---|---|
| $d \leq 150$ | 3 |
| $150 < d \leq 250$ | 4 |
| $250 < d \leq 400$ | 5 |
| >400 | 6 |

The distance from the forward end of the keyway to the big end of conical portion of the shaft is not to be less than 0.2 times the diameter of the big end.

There is to be a clearance between the top of the key and the boss. The lateral sides of the key are to be in close contact with those of the keyways in the screwshaft and the propeller boss. The bottom of the keyways are to be provided with a smooth fillet, and the fillet radius is not to be less than 1.25% of the diameter of the big end of the cone.

Keys are to be secured to the shafts by screws. The forward screw is to be placed at least 1/3 of the length of the key from the end. The depth of the screw holes is not to exceed the diameter of screw holes, and the edges of the holes are to be beveled.

The outside diameter of the threaded end for the propeller retaining nut is not to be less than 60% of the calculated diameter of the propeller shaft.

11.4.4.3 Where the torques are transmitted completely by the keys, the effective sectional area of the key in shear is not to be less than the value determined by the following formula, and the tensile strength of the material is to be equal to or greater than that of the shaft material:

$$BL \geqslant \frac{d^3}{2.35 d_m} \qquad \text{mm}^2$$

where: $B$ — breadth of the key, in mm;

$L$ — effective length of the key, in mm;

$d$ — diameter required for the intermediate shaft, in mm, to be taken as 800 N/mm$^2$ when the tensile strength of intermediate shaft material is greater than 800 N/mm$^2$ during calculation;

$d_m$ — diameter of shaft at mid-length of the key, in mm.

11.4.4.4 The fitting of a keyed propeller is preferable to meet the following requirements, and the size of keys may be suitably reduced:

(1) the safety factor of friction force against sliding is not to be less than 1.0 at sea water temperature of 35℃;

(2) the inner surface pressure of propeller boss is not to be less than 20 MPa at sea water temperature of 15℃;

(3) the equivalent uniaxial stress at the inner surface of propeller boss is not to be more than 35% of the specified minimum yield stress of the material concerned at sea water temperature of 0℃.

### 11.4.5 Fitting of keyless propeller by oil shrink method

11.4.5.1 Where keyless fitting propellers with oil pressure, the axial pull-up length from propeller boss to shaft is to be in compliance with the requirements of 11.4.5.2.

11.4.5.2 The maximum equivalent uniaxial stress in the boss at 0℃ based on the Mises-Hencky criterion is not to exceed 70% of the yield point or 0.2% proof-stress (0.2% offset yield strength) for the propeller material based on the test piece value. For cast iron, the value is not to exceed 30% of the nominal tensile strength.

Where keyless fitting propellers with oil pressure, the axial pull-up length $S$ from propeller boss to shaft may also meet the formulae given below:

Minimum required surface pressure at 35℃:

$$P_{35} = \frac{S_F T}{AB}\left(-\frac{S_F K}{2} + \sqrt{\mu^2 + B\left(\frac{F_v}{T}\right)^2}\right) \qquad \text{N/mm}^2$$

Minimum pull-up length at 35℃:

$$S_{35} = P_{35}\frac{d_1}{K}\left(\frac{1}{E_2}\left(\frac{K_2^{\ 2}+1}{K_2^{\ 2}-1}+\mu_2\right)+\frac{1}{E_1}(1-\mu_1)\right) \quad \text{mm}$$

Minimum pull-up length at temperature $t$ ($t < 35℃$ ):

$$S_t = S_{35} + \frac{d_1}{K}(a_2 - a_1)(35 - t) \quad \text{mm}$$

Corresponding minimum surface pressure at temperature $t$:

$$P_t = P_{35}\frac{S_t}{S_{35}} \quad \text{N/mm}^2$$

Minimum push-up load at temperature $t$:

$$W_t = AP_t\left(\mu + \frac{K}{2}\right) \quad \text{N}$$

Maximum permissible surface pressure at 0℃:

$$P_{\max} = \frac{0.7R_{eH}(K_2^2-1)}{\sqrt{3K_2^4+1}} \quad \text{N/mm}^2$$

Maximum pull-up length at 0℃:

$$S_{\max} = \frac{P_{\max}}{P_{35}}S_{35} \quad \text{mm}$$

Maximum pull-up length at 35℃:

$$S_{max} = \frac{P_{max}}{P_{35}}S_{35} - \frac{35(\alpha_2 - \alpha_1)d_1}{K} \quad \text{mm}$$

where: $B = \mu^2 - \frac{S_F^2 K^2}{4}$

$$F_v = \frac{2000CM_e}{d_1} \quad \text{N}$$

$$T = 1762\frac{N_e}{V} \quad \text{N}$$

$S_F$ — factor of safety against friction slip at 35℃, not to be less than 2.8 under the action of rated torque (based on rated power r.p.m.) plus torque due to torsionals;

$T$ — rated thrust, in N;

$V$ — ship speed at rated horsepower, in kn;

$\mu$ — coefficient of friction between mating surfaces. For the oil injection method, the coefficient of friction is to be 0.13 for bosses made in copper-based alloy and steel;

$F_v$ — shear force at interface, in N;

$M_e$ — rated torque corresponding to $N_e$ and $n_e$, in Nm;

$C$ — constant:

$C$ = 1 for turbines, geared diesel drives, electric drives and for direct diesel drives with a hydraulic or an electromagnetic or high elasticity coupling;

$C$ = 1.2 for a direct diesel drive.

The $c$ constant is increased if the shrinkage has to absorb an extreme high pulsating torque.

Maximum pull-up length at 35℃:

$$S_{\max} = \frac{P_{\max}}{P_{35}}S_{35} - 35(\alpha_2 - \alpha_1)d_1 / K \quad \text{mm}$$

where: $K$ — taper of the propeller shaft cone, $K \le 1/15$;

$N_e$ — rated output transmitted to the propeller shaft, in kW;

$n_e$ —propeller speed at rated output $Ne$, in r/min;

$A$ —100% theoretical contact area of propeller boss and propeller shaft, in mm$^2$, as

read from drawings and disregarding oil grooves;

$$K_2 = \frac{d_2}{d_1}$$

$d_1$ —diameter of propeller shaft at the midpoint of the taper in the axial direction, in mm;

$d_2$ — mean outer diameter of the propeller boss at the axial position corresponding to $d_1$, in mm;

$\mu_1$ — Poisson's ratio for shaft material, see Table 11.4.5.2;

$\mu_2$ — Poisson's ratio for propeller material l, see Table 11.4.5.2;

$E_1$ — modulus of elasticity of propeller shaft material, see Table 11.4.5.2;

$E_2$ — modulus of elasticity of propeller material, see Table 11.4.5.2;

$t$ — temperature at time of fitting propeller on shaft, in℃;

$\alpha_1$ — coefficient of linear expansion of propeller shaft material, see Table 11.4.5.2;

$\alpha_2$ — coefficient of linear expansion of propeller material, see Table 11.4.5.2;

$R_{eH}$ — yield point or 0.2% proof stress of propeller material, in N/mm$^2$.

**Material factor** **Table 11.4.5.2**

| Material | Modulus of elasticity | Poisson's ratio | coefficient of linear expansion (1/℃) |
|---|---|---|---|
| Cast and forged steel | $20.6\times10^4$ | 0.29 | $12\times10^{-6}$ |
| Cast iron | $9.8\times10^4$ | 0.26 | $12\times10^{-6}$ |
| Copper-based alloy Cu1 and Cu2 | $10.8\times10^4$ | 0.33 | $17.5\times10^{-6}$ |
| Copper-based alloy Cu3 and Cu4 | $11.8\times10^4$ | 0.33 | $17.5\times10^{-6}$ |

11.4.5.3 Where keyless propellers are fitted by the oil shrink method at a temperature below 0℃, the ambient temperature for fitting the propeller to the shaft is not to be less than the value calculated by the following formula:

$$t_{\min} = \frac{KP_{\max}S_{35} - P_{35}KS_{35} - 35P_{35}d_1(\alpha_2 - \alpha_1)}{P_{35}d_1(\alpha_1 - \alpha_2)} \quad ℃$$

11.4.5.4 Prior to final pull-up, the contact area between the mating surfaces is to be checked and is not to be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable. After final pull-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

11.4.5.5 Prior to final pull-up, the propeller and shaft are to be at the same temperature and the mating surfaces are to be clean and free from oil or grease. The bedding of the propeller with the shaft is to be demonstrated in the workshop to the satisfaction of the Surveyor.

11.4.5.6 A copy of the fitting curve relative to temperature, and data of corresponding loads are to be kept on board. Special tools for fitting and dismantling purposes are also to be provided on board.

11.4.5.7 The formulae given in 11.4.5.2, for the ahead condition, will also give sufficient safety in the astern condition. The formulae are applicable for solid shafts only and are not applicable for propellers where a sleeve is introduced between shaft and boss.

# CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

## Section 1 GENERAL PROVISIONS

### 12.1.1 General requirements

12.1.1.1 The arrangement of shafting and the scantlings of shafts are, in addition to the provisions of Chapter 11 of this PART, to comply with the requirements of this Chapter. The whole shafting could only be finally approved after the previous approval of the torsional, axial and lateral vibrations as well as the alignment of the said shafting.

12.1.1.2 Calculations for vibration and alignment of shafting are to be submitted for approval. Reports on measurements as deemed necessary are to be submitted for approval or information.

12.1.1.3 Novel and sophisticated shafting may be approved provided that measurement reports for similar installations are available and proved to be in compliance with the provisions of this Chapter.

12.1.1.4 Where changes are subsequently made to a shafting which has been approved, e.g. by fitting a highly flexible coupling, changing the size of shaft bearings and the engine type, or fitting a gearbox or a propeller of a different design, or changing the number of bearings etc. revised calculations of shaft vibration and alignment are to be made as appropriate and submitted for approval.

12.1.1.5 Calculations of shaft vibration and alignment are to include the detailed specifications and documents necessary for approval and checking.

### 12.1.2 Restricted speed ranges

12.1.2.1 Restricted speed ranges will be imposed in the regions of resonant speeds $n_c$, where amplitudes or stresses or torques resulting from shaft vibration exceed the limiting values for continuous running as specified in this Chapter. The engine is not to be run continuously in such restricted speed ranges.

12.1.2.2 The following speed range is to be avoided:

$$\frac{16n_c}{18-r} \sim \frac{(18-r)n_c}{16}$$

where: $r = n_c/n_e$, $n_e$ being the rated speed (r/min).

12.1.2.3 The restricted speed range for continuous operation may be suitably extended where amplitudes or stresses or torques resulting from vibration approach the limiting values for transient running as specified in this Chapter, and may be adequately reduced where they marginally exceed the limiting value for continuous running.

12.1.2.4 Restricted speed ranges may also be ascertained by measurements, i.e. the range of speed to be avoided for continuous running may be taken as that over which the measured values of amplitudes, or stresses, or torques resulting from shaft vibration are in excess of those allowed for continuous running, having regard to the tachometer accuracy.

12.1.2.5 Where the torsional vibration causes hammering of transmission gears or where the pulsatory torque of the elastic elements exceeds the allowable value for continuous running, restricted speed ranges are also to be imposed.

12.1.2.6 Where restricted speed ranges are imposed, the tachometer accuracy is to be within ±2% in way of the restricted speed range.

12.1.2.7 Restricted speed ranges are to be marked red on the tachometer, and notice boards are to be fitted in front of the control stations.

### 12.1.3 Measurements

12.1.3.1 Manufacturers are required to carry out torsional and axial (if required) vibration measurements on benches to their products of a new design or having undergone a major alteration, and to have all the equivalent parameters checked.

12.1.3.2 Whether measurements are required for verification may be decided, depending upon the conditions of the method of calculation, the magnitudes of amplitudes or stresses or torques contained in the calculations submitted. The vibration measurements may be dispensed with provided that measurement reports for similar installations are submitted and proved to be in compliance with the provisions of this Chapter.

12.1.3.3 The instrumentation, measured points and a series of revolution step of vibration measurements are to be such that they can correctly demonstrate the characteristics of vibration mode to be measured. Alternating torsional stresses are amplitudes of the maximum and minimum torsional stresses, which can be measured in relevant conditions of repetitive cycle process.
12.1.3.4 Where the difference between the measured and calculated values of natural vibration frequency is less than ±5%, the amplitudes or stresses (torque) at any cross-section of the system may be generally estimated by the measured amplitudes or stresses (torque) in accordance with the vibration mode under consideration.
12.1.3.5 The measurement reports of torsional vibration are to include order, angular amplitude or stress, natural frequency, torsional vibration of each shaft, vibratory torque of the gear and elastic couplings (where applicable) at each measuring point under test speed, and to make stress/torque and speed curves with the allowable value.
12.1.3.6 During measurement, the main engine is to start from the minimum steady speed to the rated speed, and the measurement is to be carried out under the condition of different speed and steady speed. Near the resonance speed, the speed separation is to be reduced appropriately.
12.1.3.7 In general, torsional vibration is to be measured in the following cases:
(1) the calculated torsional vibration stress has reached 70% of that permitted for continuous operation or over within the normal speed range of $r = 0.8$ to 1.0;
(2) the calculated torsional vibration stress is less than, but has reached 90% of that permitted for transient operation within the speed range of $r < 0.8$;
(3) certain novel shafting systems contain unconventional parts.

### 12.1.4 Miscellaneous
12.1.4.1 Where the bed-plates of machinery are installed on resilient mountings, the shafting is to be elastically connected.
12.1.4.2 The method of calculation and the particulars to be submitted in relation to the requirements of this Chapter may refer to CCS Guidelines for Vibration Control on Board Ships.
12.1.4.3 The pressure gauge and lower pressure alarm or amplitude monitoring device for oil supply are to be fitted for torsional or axial vibration dampers, for which the oil is supplied from the lubricating oil circulating system for main engine, unless effective measures are to be taken to identify the normal work of the vibration dampers.
12.1.4.4 The allowable stress of torsional vibration and allowable amplitude values of axial vibration may also be ascertained in accordance with Appraisal of Crankshaft Strength of Diesel Engines in Appendix 3, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.
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## Section 2 TORSIONAL VIBRATION

### 12.2.1 Application
12.2.1.1 The requirements of this Section are applicable to the following systems:
(1) main diesel engine propulsion systems, except in the case of ships classed for port service when fitted with engines having powers less than 110 kW.
(2) auxiliary diesel engine systems used for essential services, where the power developed by the auxiliary engines is 110 kW or over.
(3) propulsion systems formed by turbines;
(4) propulsion systems formed by electric motors.

### 12.2.2 Torsional vibration calculations
12.2.2.1 Torsional vibration calculation is to include: engine type, rated power, rated speed, shafting arrangement, tensile strength of shaft, equivalent parameters of torsional vibration for the dynamic system with necessary specification, Holzer tables for each vibration node under consideration and the associated vectorial sums of relative amplitudes, vibratory response calculation of main harmonics and the corresponding permissible values.
12.2.2.2 Where installations have different application conditions, e.g. combined with clutches, P.T.O. systems or having more than one engine, the torsional vibration calculations are to be

carried out for each case.

12.2.2.3 Where there is considerable difference between the sizes of the spare propeller and the working propeller, torsional vibration is also to be calculated for the condition when the spare propeller is used.

12.2.2.4 The special speed requirements for prolonged periods in service are also to be indicated, e.g. the range of the service speed of a controllable pitch propeller and the range of the service speed of a P.T.O. system, etc.

12.2.2.5 Where controllable pitch propellers are fitted, torsional vibration calculations for zero and full pitches are to be carried out.

12.2.2.6 Torsional vibration calculation is to be carried out with one cylinder misfiring in addition to that under normal working condition.

12.2.2.7 In general, the calculation is to cover the resonant conditions arising from all harmonic torque excitation up to order 12, in a speed range of 0.8 $n_{min}$ to 1.2 $n_e$ ($n_{min}$ being the minimum steady speed, in r/min). For diesel engine propulsion system, if energy method is adopted to calculate torsional vibration, the calculation of non-resonant condition over 1.2 $n_e$, resulting from the main harmonic of one node vibration, is also to be carried out.

### 12.2.3 Allowable stresses

12.2.3.1 The allowable torsional vibration stresses for shafting are to be calculated based on the basic diameters of the shafts, i.e. the crankpin diameter for crankshafts, the minimum diameter for intermediate shafts and the minimum diameter between the aft bearing and the bulkhead gland for screwshafts, and the effect of the stress concentration on the plain sections of the shafting may be neglected.

12.2.3.2 The allowable torsional vibration stresses for main engine crankshafts are not to exceed the values given by the following formulae:

Continuous running $(0 < r \leq 1.0)$:

$$[\tau_c] = \pm [(52-0.031d)-(33.8-0.02d)\, r^2] \quad N/mm^2$$

$(1.0 < r \leq 1.05)$:

$$[\tau_c] = \pm [(18.1-0.0113d)+(87.3-0.052d)\sqrt{r-1}] \quad N/mm^2$$

Transient running $(0 < r < 0.8)$:

$$[\tau_t] = \pm 2.0\, [\tau_c] \quad N/mm^2$$

The symbols used in 12.2.3.2 to 12.2.3.4 are defined as follows:

$[\tau_c]$ — allowable torsional vibration stress for continuous running, in N/mm$^2$;

$[\tau_t]$ — allowable torsional vibration stress for transient running, in N/mm$^2$;

$d$ — basic diameter of shafts, in mm;

$r = n_c/n_e$;

$n_c$ — critical speed, in r/min;

$n_e$ — rated speed, in r/min.

12.2.3.3 High cycle fatigue criterion (typically >> $10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The influence of reverse bending stresses is addressed by the safety margins, see the provisions of 11.2.2, Chapter 11 of this PART.

The allowable torsional vibration stresses for thrust, intermediate, tube shafts and screwshaft are not to exceed the values given by the following formulae:

Continuous running $(0 < r < 0.9)$:

$$[\tau_c] = \pm C_W C_K C_D\, (3-2\, r^2) \quad N/mm^2;$$

$(0.9 \leq r \leq 1.05)$:

$$[\tau_c] = \pm 1.38\, C_W C_K C_D \quad N/mm^2;$$

Transient running $(0 < r \leq 0.8)$:

$$[\tau_t] = 1.7\, [\tau_c] / \sqrt{C_K} \quad N/mm^2$$

where: $C_W$ — material factor; $C_W = (R_m + 160)/18$;

$R_m$ — specified tensile strength of shaft material, in N/mm$^2$. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 600 N/mm$^2$ for $R_m > 600$ N/mm$^2$; when alloy steel is used, it is to be taken as 800 N/mm$^2$ for $R_m > 800$ N/mm$^2$. For special approval of alloy steel used for intermediate shaft material, the tensile

strength of shaft material may be greater than 800 N/mm$^2$, but less than 950 N/mm$^2$, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness ② and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of CCS Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm$^2$ for $R_m$> 600 N/mm$^2$;

$C_K$ — shape coefficient, see Table 12.2.3.3;

$C_D$ — size factor: $C_D = 0.35+0.93\ d^{-0.2}$. The size factor being a function of diameter only does not purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

**Shape coefficient $C_K$** **Table 12.2.3.3**

| Intermediate shafts | | | | | | Thrust shafts | | Propeller shafts and tube shafts | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Integral coupling flange | Shrink fit coupling | Keyway, tapered connection | Keyway, cylindrical connection | Radial hole | Longitudinal slot | On both sides of thrust collar | In way of axial bearings where roller bearing is used as thrust bearing | Flange mounted or keyless taper fitted propeller shafts | Key fitted propeller shafts | The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead |
| 1.0① | 1.0① | 0.6 | 0.45 | 0.50 | 0.30② | 0.85 | 0.85 | 0.55 | 0.55 | 0.8 |

Notes: ① For multiple-arc transition intermediate shaft, if $C_K$ is greater than 1, the testing basis or service experience is to be provided.

② $C_K$ = 0.3 is a safe approximation within the limitations in note 4 of Table 11.2.2.1. More accurate estimate of the shape coefficient $C_K$ may be determined by direct application of FE calculation or the following formula. In which case:

$$C_K = \frac{1.45}{scf}$$

where: *scf* — stress concentration factor, which is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots), to be calculated according to following formula:

$$scf = 2.3 + 0.8 \times \frac{(l-e)/d}{\sqrt{(1-d_0/d)\times e/d}}$$

$l$ — length of slot, in mm;

$e$ — width of slot, in mm;

$d$ — basic diameter of shaft, in mm;

$d_0$ — actual bore of shaft, in mm.

This formula applies to:

- slots at 120 or 180 or 360 degrees apart.
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$$\alpha_{t(hole)} = 2.3 - 3\times\frac{e}{d} + 15\times\left(\frac{e}{d}\right)^2 + 10\times\left(\frac{e}{d}\right)^2 \times\left(\frac{d_i}{d}\right)^2$$

$\alpha_{t(hole)}$ represents the stress concentration of radial holes or simplified to 2.3.

12.2.3.4 The allowable torsional vibration stresses for the crankshafts and transmission shafts of diesel engines for generators and of auxiliary diesel engines for essential services and for the crankshafts of propulsion diesel engines running with constant speed are not to exceed the values given by the following formulae:

Continuous running $(0.9 \le r \le 1.05)$:

$$[\tau_c] = \pm (21.59 - 0.0132d) \quad \text{N/mm}^2;$$

Transient running $(0 < r < 0.95)$:

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

$$[\tau_t] = \pm 5.5\,[\tau_c] \quad \text{N/mm}^2.$$

12.2.3.5 For propulsion shafting running at constant speed, higher vibratory stress limits may be considered if background of service experience is provided.

12.2.3.6 Except the shafting material is of nodular graphite cast iron, the tensile strength of intermediate shaft material specified in 12.2.3.2 and 12.2.3.4 is greater than 430N/mm$^2$, the allowable stress $\tau'$ may be calculated by the following formula:

$$\tau' = \frac{R_m + 184}{614}\tau \quad \text{N/mm}^2$$

where: $R_m$ — tensile strength of shaft material, in N/mm$^2$, to be taken as 600 N/mm$^2$ for $R_m > 600$ N/mm$^2$;

$\tau$ — allowable torsional vibration stress determined by 12.2.3.2 and 12.2.3.4 of this Section, in N/mm$^2$.

**12.2.4 Additional requirements for generators**

12.2.4.1 In the case of alternating current generators, the resultant vibration amplitudes at the rotor are not to exceed 3.5° electrical degrees under rated load working conditions. Where the inverter provided with rectification can ensure the output of stable power supply to the grid for normal use, the electrical degree is not limited to 3.5°.

12.2.4.2 The vibratory inertia torques imposed on the generator rotors are to be limited to ± 2 $M_e$ over the speed range of $r$ = 0.95 to 1.10 ($M_e$ being the torque at the rated speed), and to ± 6 $M_e$ over the range of $r < 0.95$. Where a main engine drives two or more generators, the rated torque of each generator is to be taken into consideration separately.

**12.2.5 Allowable vibratory torques for gearing and flexible coupling**

12.2.5.1 The vibratory torque at gear engagement of the transmission gearing arrangements is not, in general, to exceed 1/3 of the rated full load mean torque in the range of $r$ = 0.9 to 1.05. In cases where tooth surface contact stress and root bending stress of gears are less than the allowable values specified in Appendix 1, Chapter 10, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, special consideration will be given to the acceptance of higher vibratory torque on the gears, but gear knock does not happen.

12.2.5.2 Flexible couplings are to be of such design that vibratory torque of the elastic elements is not to exceed the allowable pulsatory torque for continuous running and not to exceed the allowable pulsatory torque for transient running in the respective running conditions.

12.2.5.3 On the power output branch without load, the vibratory torque at gear engagement is not, in general, to exceed 20% of the rated full load mean torque.

**12.2.6 Miscellaneous**

12.2.6.1 No critical speed is to occur in the range of speed for normal service or in any special speed ranges required for service.

12.2.6.2 Restricted speed ranges in normal operating conditions ($r$ = 0.8 to 1.0) are not acceptable.

12.2.6.3 The torsional vibration stresses caused by the upper flank at $r$ = 0.8 are not to exceed the allowable stress $[\tau_c]$.

12.2.6.4 Resulted stresses arising from resonance and major non-resonance are not to exceed 1.5 times the allowable torsional vibration stresses limited by this Section in the range of $r$ = 0.8 to 1.05.

12.2.6.5 Where data from experience or detailed calculations are furnished by manufacturers, allowable torsional vibration stresses (or torques) as supplied by the manufacturers may be adopted.

12.2.6.6 The allowable torsional vibration stresses for crankshafts may also be obtained in accordance with the Unified Requirements of IACS. However the calculations are to be submitted in accordance with the requirements in Appendix 3, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

# Section 3 AXIAL VIBRATION

**12.3.1 General requirements**

12.3.1.1 For all main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive axial vibration amplitudes throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for reducing the amplitudes are to be provided as appropriate.

12.3.1.2 Documents of axial vibration characteristics of the slow-speed two-stroke diesel engine direct propulsion shafting systems and of the turbine propulsion shafting systems are to be submitted for approval.

**12.3.2 Axial vibration calculations**

12.3.2.1 Axial vibration calculations are to include: engine type, rated power, rated speed, shafting arrangement, equivalent parameters of systems and the necessary specification, the Holzer tables of 0-node and 1-node vibration and the associated vectorial sums of relative amplitudes difference, the vibratory response of major harmonics and the associated limits.

**12.3.3 Allowable amplitudes**

12.3.3.1 For diesel engine propulsion shafting systems, axial vibration amplitudes for continuous running arising from axial vibration in the range of r=0 to 1.0 are not to exceed the values calculated by following formula:

$$[A_{a1}] = \frac{R[\Delta a_0]}{2(\Delta a_k)_{\max}(R + \frac{d_j}{2})} \quad \text{mm}$$

where: $[A_{a1}]$ — allowable axial vibration amplitude for continuous running at the free-end of the crankshaft, in mm;

$(\Delta_{ak})_{max}$ — the maximum relative amplitude difference in the crankshaft of the axial vibration mode under consideration, in mm;

$d_j$ — the main journal diameter of the crankshaft, in mm;

$[\Delta_{a0}]$ — the maximum allowable difference between crank webs, in mm;

$R$ — radius of the crank, in mm.

12.3.3.2 Allowable axial vibration amplitudes for transient running are in general, to be 1.5 times those for continuous running.

12.3.3.3 Where allowable values for continuous running are exceeded, restricted speed ranges are to be imposed. Generally, axial vibration amplitudes caused by resonance or the upper flank at $r$ = 0.85 are not to exceed the allowable values for continuous running, and those caused by resonance or the lower flank at $r$ = 1.0 are not to exceed the allowable values for continuous running.

12.3.3.4 Where data from experience or detailed calculations are furnished by manufacturers, allowable axial vibration amplitudes as supplied by the manufacturers may be adopted.

# Section 4 WHIRLING VIBRATION

**12.4.1 General requirements**

12.4.1.1 For main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive amplitudes due to whirling vibration throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for frequency modulation are to be provided as appropriate.

12.4.1.2 For the propulsion shafting systems with brackets and cardan shafts, details of the whirling vibration characteristics are to be submitted for approval.

**12.4.2 Whirling vibration calculations**

12.4.2.1 Whirling vibration calculations are to include: engine type, rated power, rated speed, speed ratio (where applicable), shafting arrangement, lengths and positions of bearings, bearing

materials, propeller mass and inertia, the resonant speed of 1 order and blade orders forward and backward whirling vibrations.

12.4.2.2 During whirling vibration calculation, bearing stiffness are to be taken into account, and the load distribution on bearings is also to be considered.

### 12.4.3 Speed ranges to be avoided

12.4.3.1 For the shafting systems with brackets and cardan shafts, the blade order forward whirling resonant speeds are not to appear in the range of $r$ = 0.85 to 1.0, and 1 order forward whirling resonant speeds are to be 20% more than the rated speed.

## Section 5 SHAFTING ALIGNMENT

### 12.5.1 General requirements

12.5.1.1 The alignment of main propulsion shafting systems is to comply with the requirements of this Section. For shafting systems using environmentally acceptable lubricants, the alignment of shafting systems is to additionally comply with the requirements of Chapter 4 of the Guidelines for Surveys on Implementation of the Requirements of U.S. Environmental Protection Agency on Environmentally Acceptable Lubricants.

12.5.1.2 The alignment of main propulsion shafting systems and the arrangement of bearings are to be such as to give reasonable bending moments and bearing reactions and minimize the effects of hull deformation or bearing weardown on shafting alignment.

12.5.1.3 For the shafting alignment of large ships, the effects of hull deformation when the ship is ballasted or fully loaded are to be taken into consideration.

12.5.1.4 Shafting alignment calculations together with shafting instructions for the following main propulsion shafting systems are to be submitted for approval:

(1) shafting systems where the propeller shaft has a diameter (hereinafter referred to as propeller shaft diameter) of 250 mm or greater in way of the aftermost sterntube bearing;

(2) shafting systems fitted with no sterntube forward bearing where the propeller shaft diameter is 200 mm or greater;

(3) shafting systems with speed reduction gear, of which the wheel is driven by two or more than two pinions;

(4) shafting systems for which the sterntube bearings are to be slope-bored or inclined;

(5) shaft generator or electrical motor as an integral part of the low speed shaft in diesel engine propulsion.

12.5.1.5 Shafting alignment instructions are to correctly reflect the calculation results for the alignment in cold condition, containing at least the contents of 12.5.4 and 12.5.5 of this Section.

12.5.1.6 In respect to shafting systems where the propeller shaft diameter is less than 250 mm, shafting alignment calculations may not be submitted. The span of bearings etc. are to be included in the shafting strength calculations required by subparagraph 11.1.4.1(4), Chapter 11 of this PART, referring to the relevant requirements for shafting alignment in Chapter 9 of CCS Guidelines for Shipboard Vibration Control. In addition, the technological documents submitted by the shipyard regarding shafting alignment are to contain alignment instructions.

### 12.5.2 Shafting alignment calculations

12.5.2.1 Shafting alignment calculation results are to comply with the requirements of 12.5.3.

12.5.2.2 For a propulsion shafting system directly driven by a diesel engine, shafting alignment calculations are generally to be performed up to the 1st main bearing at the free end of the engine. For a gear-driven shafting system, shafting alignment calculations are to be performed up to the fore end of the gear wheel.

12.5.2.3 In shafting alignment calculations, the influence of thermal expansion of heated bearings (e.g. 55℃) during operation of the engine or gearbox and so far as possible, the influence of expansion of heated tanks (e.g. 45℃) in double bottom that are located below intermediate shaft bearings, are to be taken into account.

12.5.2.4 In shafting alignment calculations, the influence of different ambient temperatures (taken as 0℃, 10℃ or 20℃) on the installation of shafting systems is to be taken into account so far as practicable.

12.5.2.5 Shafting alignment calculations are to include engine type, rated power, rated speed, shafting arrangement, all point loads and their acting positions, positions and lengths of bearings, allowable bending moments and shearing forces at the output flange of diesel engines, allowable loads of individual bearings, bearing clearances, relative slope between the propeller shaft and the aftermost sterntube bearing, gearbox information and allowable load difference between fore and aft bearings of the gear wheel.

12.5.2.6 The shaft deflection, the bending moments or stresses, shear forces, and angles at different shaft sections, the loads and reaction force influence numbers of bearings obtained during reasonable shafting alignment in both cold and hot conditions are to be submitted. For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the shaft deflection, relative angle and bearing loads at the zero rudder angle as a minimum under rated speed are to be provided, taking into account hydrodynamics of propellers. The calculation results are to comply with the requirements of 12.5.3.2 and 12.5.3.7.

12.5.2.7 A bearing load measurement procedure is to be submitted, covering actual measurements, jacking positions and jack correction factors.

12.5.2.8 The sag and gap values of each couple of flanges for the installation of shafting systems (shaft flanges being not connected) are to be provided.

12.5.2.9 For slope-bored sterntube bearings or bearing inclinations, a detailed description of slope bores or bearing inclinations is to be provided.

### 12.5.3 Shafting alignment requirements

12.5.3.1 In the static condition, all bearing loads are to be positive, i.e. there is to be no voidable bearing load. The bearing load is generally not to be less than 20% of the sum of all weights between two adjacent spans.

12.5.3.2 Bearing loads are in general not to exceed the values specified below or by the manufacturer:

aftermost sterntube bearings: as specified in 11.2.5.1, Chapter 11 of this PART;

sterntube forward bearings: 0.8 $N/mm^2$;

nonmetallic sterntube bearings: 0.3 $N/mm^2$;

intermediate shaft bearings: 0.8 $N/mm^2$;

gear shaft bearings: 1 $N/mm^2$;

main bearings of diesel engines: as specified by the engine manufacturer.

12.5.3.3 Additional bending stresses of shafts are generally not to exceed the following values:

propeller shafts and sterntube shafts: 20 $N/mm^2$;

intermediate shafts: 20 $N/mm^2$;

thrust shafts: 15 $N/mm^2$;

gear wheel shafts: 10 $N/mm^2$ or as specified by the gearbox manufacturer.

12.5.3.4 The bending moments and shearing forces applied to the output flange of diesel engines are not to exceed those as specified by the engine manufacturer (if required). The minimum load of main bearings of main engines is in general not to be less than 10% of the allowable load on main bearings. Alternatively, the minimum value specified by the engine manufacturer may be accepted, but this is to be reflected in shafting alignment calculations.

12.5.3.5 The load difference between fore and aft bearings of the gear wheel of the gearbox is to meet the relevant requirements of the manufacturer, generally not exceeding 20% of the sum of the weight of the shaft portion between the two bearings and that of the gear wheel.

Where the alignment calculation results in running condition are provided and the bearing structure is confirmed to be determined according to the acting angle of the resultant force in the running condition, the load difference between fore and aft bearings may not be limited to 20% as specified above provided that the relevant requirements of Appendix 1, Chapter 10 of this PART are complied with.

12.5.3.6 The relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed $3.0 \times 10^{-4}$ rad in the static condition.

12.5.3.7 For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed $3.0 \times 10^{-4}$ rad in the static condition and in the running condition considering

hydrodynamics of propellers. Alternative recognized model technology may be accepted, e.g. multi-point support bearing model or fluid structure three dimensional FE model of interaction between bearing oil film and rotating shaft. Appropriate assumption and recognized modelling methods are to be indicated in the submitted report. The calculated oil film thickness in each analytical condition is not to be less than the minimum thickness value established for the oil film. Such criteria may replace aftermost bearing relative angle criteria.

**12.5.4 Conditions for shafting alignment**

12.5.4.1 The ship's superstructures, main engines, boilers, generators and other pieces of essential equipment are to have been hoisted to their respective places. There is to be no movement of essential equipment or change of ballasting during the alignment, installation and inspection on board.

12.5.4.2 The processing and welding of hull portions within shafting areas are to have been completed.

12.5.4.3 The temperatures of hull structures are to be stable and so far as practicable, uniform.

12.5.4.4 The installation of sterntube arrangements has been completed.

12.5.4.5 Where the ship is afloat, consideration is to be given to measures for preventing movement or rotation of the propeller shaft.

12.5.4.6 Where the ship is in a normal floating condition, the immersion of the propeller is to be so close as practicable to that indicated in calculations.

**12.5.5 Shafting alignment procedure**

12.5.5.1 Where the conditions specified in 12.5.4 are met, shafting alignment may be performed according to the approved alignment calculations or alignment technology (as specified in 12.5.1.4 or 12.5.1.6).

12.5.5.2 Where any noncompliance with calculation conditions (e.g. the ambient temperature, propeller immersion, ship's condition, load adjustment of main bearings of engines) may affect the alignment results during the installation of shafting systems, the alignment calculations together with alignment instructions are to be resubmitted for approval, unless such effects have been included in the calculations.

12.5.5.3 The shipyard is to give full consideration to the influence of deflection of boring equipment on the machining precision of stern tubes. After finishing machining of stern tubes, sizes of bores on stern tubes are to be measured to confirm the deviation of center lines of the stern tube body. Such deviation is to be taken into consideration during cylindrical grinding of stern bearing and compensation during machining is to be made for deviation from stern tube center line as appropriate.

12.5.5.4 After stern bearing is pressed and fitted, slope at stern bearing is to be measured. After the integrated stern tubes are poured and installed, slope at stern bearing is to be measured.

12.5.5.5 Where the load of the sterntube forward bearing is not positive for unconnected shafting flanges, the force applied downward from the propeller shaft forward flange is to comply with the calculations.

12.5.5.6 The axial distance of temporary supports, if fitted, is to comply with the calculations.

12.5.5.7 For shafting alignment, the propeller shaft forward flange is to be used as the reference for positioning bearings or temporary supports and the engine (or gearbox) from aft to fore by adjusting the sag and gap of unconnected flange pairs, in compliance with the relevant requirements.

12.5.5.8 The sag and gap tolerances of flange pairs for straight alignment shafting are to comply with the requirements of 12.5.6.1 and to be recorded.

12.5.5.9 The sag and gap values of flange pairs for the reasonable alignment shafting are to comply with the shafting alignment calculations and tolerances are to comply with the requirements of 12.5.6.1. After connection of flanges, at least a load verification is to be carried out on stern tube forward bearing (if any), intermediate bearing, last three bearings of the main engine (direct transmission propulsion system), wheel shaft bearing (if any) with the ship afloat, and tolerances are to comply with the requirements of 12.5.6.2 and appropriate records are to be made.

12.5.5.10 At the time of completing the shafting alignment, the gear engagement is to be examined or the difference between crank webs of engine measured, and the results are to comply

with the requirements of 12.5.6.3 or 12.5.6.4 and appropriate records are to be made.

12.5.5.11 After completion of shafting alignment, coupling bolts are to be provided to flanges, chocks provided or epoxy resin cast to diesel engines (or gearboxes) and engine foundation bolts provided, followed by connection and fixing.

### 12.5.6 Shaft alignment survey

12.5.6.1 The sag and gap of flange pairs are to be examined, with tolerances generally not exceeding ±0.08 mm.

12.5.6.2 Where shafting alignment calculations are applied, actual bearing loads in cold condition may generally be measured by jacking up the loads. The jacking positions are to be the same as specified in calculations. Any deviation of measured loads from calculated ones is not to exceed 20% of the latter. For excessive tolerances, shafting alignment calculations may be carried out according to the measurement results which may be accepted where other requirements of 12.5.3 are still complied with. However, at least the loads of main bearings of the main engine are to be positive.

12.5.6.3 The gear engagement of gear-driven shafting systems is to be examined and the relevant requirements of the gearbox manufacturer are to be complied with.

12.5.6.4 For shafting systems directly driven by the diesel engine, the difference between crank webs of engine are to be examined and the relevant requirements of the engine manufacturer are to be complied with.

# CHAPTER 13 STEERING GEAR AND WINDLASSES

The steering gear and windlasses are to comply with the requirements in Chapter 13, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

CHINA CLASSIFICATION SOCIETY

# RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

## 2024

## PART FOUR
## ELECTRICAL INSTALLATIONS

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# CHAPTER 1 GENERAL

## Section 1 GENERAL PROVISIONS

### 1.1.1 General requirements

1.1.1.1 The requirements of this PART apply to electrical installations intended for sea-going ships engaged on domestic voyages. Unless otherwise specified in this PART, the provision and arrangement of source of electrical power of sea-going ships navigating in open sea area are to be in compliance with the requirements of PART FOUR of CCS Rules for Classification of Sea-going Steel Ships.

1.1.1.2 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be constructed and tested in compliance with the relevant provisions of this PART and requirements of Chapter 3, PART FOUR of the CCS Rule for Classification of Sea-going Steel Ships.

1.1.1.3 The electrical installations are to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.4 The electrical installations are to be such that:

(1) all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;

(2) electrical services essential for safety will be ensured under various emergency conditions;

(3) the safety of passengers, crew and ship from electrical hazards will be ensured.

### 1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) Essential services are the equipment necessary for the propulsion, steering and safety of the ship, including:

① primary essential services which need to be in continuous operation for maintaining propulsion and steering:

(a) steering gear;

(b) controllable pitch propeller installation;

(c) scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines required for propulsion;

(d) forced draught fans, feed water pumps, water circulating pumps, vacuum pumps, condensate pumps and oil burning installations for auxiliary steam boilers for the operation of primary essential services and for steam plants on steam turbine ships;

(e) azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps;

(f) electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps;

(g) electric generators and associated power sources supplying the equipment mentioned in (a) to (f) above;

(h) hydraulic pumps supplying the equipment mentioned in (a) to (f) above;

(i) viscosity control equipment for heavy fuel oil;

(j) fire pumps and other extinguishing medium pumps;

(k) navigation lights, aids and other signals;

(l) internal safety communication equipment;

(m) lighting system;

(n) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above.

② secondary essential services which need not necessarily be in continuous operation for maintaining propulsion and steering, but which are necessary for maintaining the ship's safety, e.g.:

(a) windlasses;

(b) fuel oil transfer pumps and fuel oil treatment equipment;

(c) lubricating oil transfer pumps and lubricating oil treatment equipment;

(d) pre-heaters for heavy fuel oil;

(e) starting air and control air compressors;

(f) bilge, ballast and heeling pumps;

(g) ventilating fans for engine and boiler rooms;

(h) equipment necessary for maintaining dangerous spaces in a safe condition;
(i) fire detection and alarm system;
(j) watertight closing appliances;
(k) refrigerating equipment for lowering ambient air temperature (see 1.2.1.2 of this Chapter);
(l) electric generators and associated power sources supplying the equipment mentioned in (a) to (k) above;
(m) hydraulic pumps supplying the equipment mentioned in (a) to (k) above;
(n) control, monitoring and safety systems for cargo containment systems;
(o) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above.

③ special equipment of ships that may be regarded as essential services.

(2) Non-essential services are those whose temporary disconnection will not impair propulsion and steer of the ship, nor endanger the safety of passengers, crew, cargo, ship and machinery.

(3) Emergency consumer is a consumer which, after loss of the main source of electrical power, must be supplied by the emergency source of electrical power.

(4) Main source of electrical power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

(5) Emergency source of electrical power is a source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.

(6) Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.

(7) Primary distribution system is a system having direct electrical connection with the generator.

(8) Secondary distribution system is a system having no direct electrical connection with the generator, e.g. isolated therefrom by a double-wound transformer.

(9) Low-voltage system is an alternating-current system operating with the maximum rated voltage not exceeding 1,000 V inclusive between conductors and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions does not exceed 1,500 V between conductors.

(10) High-voltage system is an alternating-current system operating with the rated voltage more than 1 kV but not exceeding 15 kV and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions exceed 1,500 V between conductors.

(11) Switch gear and control gear assembly is a combination of one or more switch gears and means of control, measurement, signal, protection and adjustment etc, assembled by the manufacturer together with all internal electrical and mechanical connectors and components.

(12) Main switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's services.

(13) Emergency switchboard is a switchboard which, normally supplied by the main switchboard, in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's emergency services.

(14) Distribution board is a switch gear and control gear assembly arranged for the control and distribution of electrical power to final sub-circuits.

(15) Final sub-circuit is that portion of a wiring system extending beyond the final over-current device of a board.

(16) Total discrimination (total selectivity) is an over-current discrimination where, in the presence of two or more over-current protection devices in series, the protective device on the load side effects the protection without causing the other protective devices to operate.

(17) Partial discrimination (partial selectivity) is an over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device on the load side effects the protection up to a given level of short-circuit current, without causing the other protective devices to operate.

(18) Back-up protection is the protection equipment or system which is intended to operate when a system fault is not cleared in due time because of failure or inability of the protective device closest to the fault to operate or because of failure of the other protective device.

(19) Continuity of power supply means that during and after a fault in a circuit, the supply to fault-free circuits is permanently ensured.

(20) Dangerous zone is a zone where flammable or explosive vapours, gases, dusts, or explosives may be

normally expected to accumulate.
(21) Enclosed space is a space enclosed by bulkheads and decks, which may be fitted with doors, windows or other openings capable of being closed.
(22) Semi-enclosed space is a space limited by top plates, wind breaks and bulkheads etc. in such a manner that the natural conditions of ventilation in the space are notably different from those obtained on open deck, and so arranged that the gas will not easily diffuse.
(23) A blackout situation means that the main and auxiliary machinery installations, including the main power supply, are out of operation, but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.
(24) Shelf life of a battery means the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.
(25) An air-lock is to have two gastight steel doors which are self-closing without any hold-back arrangement, and the distance between which is not to be less than 1.5 m and not necessarily more than 2.5 m.
(26) Ripple voltage
The amplitude of the ripple voltage is represented in Figure 1.1.2.1(26) by the difference between $U_{max}$ and $U_{min.}$

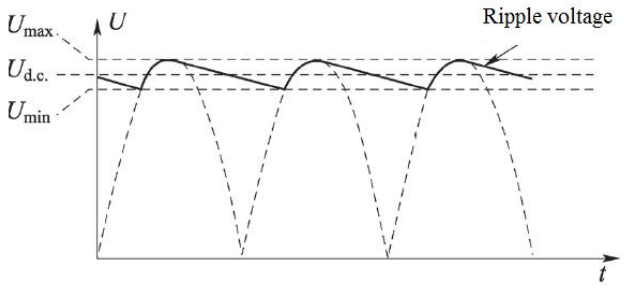



**Figure 1.1.2.1(26) Ripple Voltage**

(27) Uninterruptible power system (UPS) is a combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power in case of input power failure.
(28) Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods.
(29) Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation.
(30) Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

### 1.1.3 Plans and documents

1.1.3.1 The following plans and documents are to be submitted for approval:
(1) Electrical loading evaluation of main and emergency sources of electrical power.
(2) Calculations for short-circuit currents (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load) of more than 250 kVA).
(3) Analysis for coordination of protective devices in compliance with the requirements of 2.5.1.1 and 2.5.4.1 of this PART (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load) of more than 250 kVA, which may be omitted for non-self-propelled ships) .
(4) Diagrams of power systems, in which the following are to be indicated:
① main ratings of motors, transformers, batteries, electrical and electronic equipment;
② all feeders connected to main and emergency switchboards;
③ section boards (if fitted) and distribution boards;
④ type, cross-sectional area and current loadings of cables;
⑤ rating and setting of protective devices (such as short-circuit, overloading, reverse power and unloading protection);
⑥ remote stops;
⑦ insulation level monitoring and alarm;
⑧ interlocks..
(5) Arrangement of main electrical equipment, in which the positions of the following items are to be

indicated:

① main and emergency generators;

② main and emergency switchboards (or emergency accumulator battery charging and discharging boards);

③ emergency accumulator batteries;

④ electrical equipment for essential services (see 1.1.2.1 of this Chapter).

(6) Schematic diagrams of main lighting.

(7) Arrangement of main lighting.

(8) Schematic diagrams of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).

(9) Arrangement of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).

(10) Schematic diagrams (if supplied by emergency power) of low location lighting (if fitted).

(11) Schematic diagrams of internal communication systems, including:

① engine-room telegraph system;

② essential telephone system;

③ communication system for lifesaving;

④ engineers' alarm system.

(12) Arrangement of internal communication systems, including:

① engine-room telegraph system;

② essential telephone system;

③ communication system for lifesaving;

④ engineers' alarm system.

(13) Schematic diagrams of safety systems for the ship and persons on board, including:

① general emergency alarm system;

② public address system;

③ fire detection and fire alarm systems;

④ alarm system for closing watertight doors;

⑤ other alarm systems, e.g. for the release of fire extinguishing media (see Section 9, Chapter 2 of this PART).

(14) Arrangement of safety systems for the ship and persons on board, including:

① general emergency alarm system;

② public address system;

③ fire detection and alarm system;

④ alarm system for closing watertight doors;

⑤ other alarm systems, e.g. for the release of extinguishing media (see Section 9, Chapter 2 of this PART).

(15) Arrangement of main cable runs (for passenger ships and high voltage electrical installations).

(16) General arrangement of the ship showing dangerous zones and spaces (for oil tankers and other ships carrying dangerous explosive goods).

(17) Simplified circuit diagram of electrical propulsion system, in which the following are to be indicated:

① main ratings of motors, transformers, batteries, electrical and electronic equipment;

② type, cross-sectional area and current loadings of cables;

③ type and main rating of circuit breakers and fuses;

④ earth fault monitoring.

(18) Arrangement of control positions and stations of electrical propulsion machinery.

(19) List of monitoring and alarm items for electrical propulsion.

(20) Arrangement of semiconductor converters, including cooling system, for electrical propulsion system.

(21) Calculations of harmonic distortion for all main connectors, including main switchboards and distribution boards, in the electrical system of electrically propelled ships.

(22) All electrical equipment located in hazardous areas together with the following associated information are to be included in their arrangement plan:

① type of protection, explosion group and temperature class;

② degree of protection;

③ hazardous classification of the area where the electrical equipment is installed.

(23) Verification information[①] of intrinsically safe circuits, including the verification of the voltage, current, inductance and capacitance.

1.1.3.2 The specifications for all electrical systems of the ship may be submitted for information and additional plans and documents may be required as deemed necessary.

### 1.1.4 Testing

1.1.4.1 Electrical equipment specified in 1.1.1.2 and 1.1.2.1(1) of this Section is to be tested in accordance with the requirements of Chapter 3, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships at the manufacturer. Tests other than those specified in this PART may be required as deemed necessary.

1.1.4.2 On completion of installation on board, the electrical installations are to be subject to mooring and sea trials in accordance with test programmes which are examined and approved.

## Section 2 OPERATING CONDITIONS

### 1.2.1 Environmental conditions

1.2.1.1 Unless otherwise specified (e.g. in 1.2.1.2 of this Section), all electrical installations are to operate satisfactorily under the following environmental conditions:

(1) The ambient air temperatures and primary cooling water temperatures are as given in Table 1.2.1.1(1), however the upper limit of ambient air temperatures for the electronic equipment is to be 55℃.

**Ambient Temperature** **Table 1.2.1.1(1)**

| Medium | Location | Temperature (℃) | |
|---|---|---|---|
| | | Service area including tropical zones | Service area except in tropical zones |
| Air | In enclosed spaces | 0 ~ 45 | 0 ~ 40 |
| | In spaces subject to temperatures over 45℃(or 40℃) or below 0℃ | According to temperatures in such spaces | According to temperatures in such spaces |
| | On the open deck | -25 ~ 45 | -25 ~ 40 |
| Water | | 32 | 25 |

(2) The inclination and roll of the ship is as given in Table 1.2.1.1(2).

**Angle of Inclination** **Table 1.2.1.1(2)**

| Installations, components | Angle (°)[①②] | | | |
|---|---|---|---|---|
| | Athwartships | | fore-and-aft | |
| | Static | Dynamic | Static | Dynamic |
| Emergency power installations, switchgear, electrical and electronic appliances | 22.5 | 22.5 | 10 | 10 |
| Electrical installations excluding items stated above | 15 | 22.5 | 5 | 7.5 |

Notes: ① Athwartship and fore-and-aft inclinations may occur simultaneously.

② For ships carrying liquefied gases or chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

(3) The vibration and shock likely to arise in normal service of the ship.

(4) Moisture, sea air, oil vapour and mould.

1.2.1.2 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable may be reduced from 45℃ to a value not less than 35℃ provided:

(1) the equipment is not for use for emergency services;

(2) temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design

① The maximum inductance and capacitance which are the total of the cable out to the hazardous area plus the values of connected equipment are to be less than the rated values of associated apparatus. The values of permissible input voltage, input current of each intrinsically safe apparatus is to be greater than or equal to the values respectively of the associated apparatus. Refer to IEC publication 60079-14: “Explosive atmosphere-Part 14: Electrical installations design, selection and erection” or equivalent standards.

temperature;
(3) the equipment is able to be initially set to work safely within a 45℃ ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45℃ ambient temperature;
(4) audible and visual alarms are provided, at a continually manned control station, to indicate any malfunction of the cooling units;
(5) it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

### 1.2.2 Voltage and frequency variations

1.2.2.1 The electrical equipment supplied from the main or emergency systems is to be capable of operating satisfactorily under normally occurring variations in voltage and frequency.
1.2.2.2 Unless otherwise stated in GB or international standards, electrical equipment is to operate satisfactorily with the variations in voltage and frequency from the rated value shown in Table 1.2.2.2.

**Voltage and Frequency Variations** **Table 1.2.2.2**

| Equipment | Parameters | Permanent (%) | Transient | |
|---|---|---|---|---|
| | | | % | Max. recovery time (s) |
| General AC equipment | Voltage | +6 ~ -10 | ±20 | 1.5 |
| | Frequency | ±5 | ±10 | 5 |
| Equipment supplied by DC generators or rectifiers | Voltage | ±10 | – | – |
| | Voltage cyclic variation deviation | 5 | – | – |
| | Voltage ripple | 10 | – | – |
| Equipment supplied by batteries:<br>Connected to batteries during charging①<br>Not connected to the batteries during charging | <br>Voltage<br>Voltage | <br>+30 ~ -25<br>+20 ~ -25 | – | – |

Note: ① Different voltage variations as determined by the charging/discharging characteristics, including the ripple voltage from the charging device, are to be considered.

1.2.2.3 Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in Table 1.2.2.2 is not to be supplied directly from the system but by alternative means, e.g. through a stabilized supply.

### 1.2.3 Harmonic content

1.2.3.1 AC electrical equipment is to operate satisfactorily with a supply voltage containing a total harmonic content of the voltage waveform not exceeding 8%. Where the harmonic content may exceed 8%, attention is to be given in selecting the equipment to ensure its normal function.

## Section 3 DESIGN, CONSTRUCTION AND INSTALLATION

### 1.3.1 General requirements

1.3.1.1 Electrical equipment is to be so designed, constructed and installed as to ensure safe operation and facilitate inspection and repair.
1.3.1.2 The distance between live parts of different potential and between live parts and earthed metal, whether across surfaces or in air, is to be adequate for the working voltage, having regard to the nature of the insulating material and the conditions of service.
1.3.1.3 Equipment is not to remain alive through the control circuits or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.
1.3.1.4 All nuts and screws used for the connection and fastening of electrical equipment are to be provided with means to ensure that they cannot work loose by vibration and shock.
1.3.1.5 The material used to make electrical equipment is to comply with the following requirements:
(1) It is, in general, to be durable, flame-retardant, moisture resistant unless it is adequately protected against the atmospheric environment and temperatures to which it is likely to be exposed.
(2) Insulating materials and insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect them.

(3) The current carrying parts of electrical equipment are, in general, to be made of copper or copper alloys.
(4) Metal parts of electrical equipment are to be covered with proper protective coating against corrosion unless they are made of satisfactory corrosion-resistant material.
(5) New installation of materials which contain asbestos is to be prohibited.

1.3.1.6 If electrical fittings, not of aluminium, are connected to aluminium, suitable means is to be taken to prevent electrolytic corrosion.

1.3.1.7 All electrical equipment with internal wiring is to be attached with schematic or wiring diagrams in which wiring codes are indicated. All terminals of electrical equipment are to be provided with durable markings or symbols corresponding to those indicated in the diagrams.

1.3.1.8 The controls for emergency alarms are to be marked in red and provided with durable nameplates indicating their purposes.

1.3.1.9 For the fitting of rheostats, starting and charging resistors, heating appliances and other electrical apparatus likely to cause high temperatures, means are to be provided against overheating or igniting of adjacent objects.

1.3.1.10 All electrical equipment is not to be fitted close to the external surfaces of oil compartments, oil tanks or double bottom tanks intended for carrying oils. If this is necessary, electrical equipment is to be installed at a minimum distance of 50 mm from these surfaces, provided that the electrical apparatuses mentioned in 1.3.1.9 are strictly prohibited to be installed on such surfaces.

1.3.1.11 Generating sets are to be installed with their shafts in parallel with the fore-and-aft direction of the ship, and horizontal motors are also to be installed, as far as practicable, with their shafts in parallel with the fore-and-aft direction of the ship.

1.3.1.12 For the electrical equipment other than that installed in a dedicated compartment, the live parts having a working voltage or a voltage to earth exceeding 50 V are to be so protected that they cannot be inadvertently touched.

1.3.1.13 Where the temperature of the enclosures of the electrical equipment is in excess of 80°C, suitable means are to be provided or suitable arrangement is to be made so as to protect the operators from injurious heating due to inadvertent touching.

1.3.1.14 Holes are not to be drilled in watertight bulkheads, decks or boundary plating of deckhouses for the purpose of fitting the screws used to securing the electrical equipment and cables.

1.3.1.15 Electrical equipment and cables are not to be fitted on the shell plating.

1.3.1.16 Conductors and equipment are to be placed at a suitable distance from the magnetic compass, or are to be so screened that the interfering external magnetic field is negligible.

### 1.3.2 Protective enclosures

1.3.2.1 The type of protective enclosures for electrical equipment is to comply with IEC Publication 60529: Degrees of Protection Provided by Enclosures (IP Code) or equivalent standards.

1.3.2.2 The type of protective enclosures selected for electrical equipment is to be appropriate to the condition of the location at which such equipment is installed. The lowest degree of protection is to comply with the requirements given in Table 1.3.2.2.

**Minimum Requirements for the Degree of Protection by Enclosure Table 1.3.2.2**

| (1) | (2) | (3) | (4) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Equipment | | | | | | | |
| Location | Condition of location | Degree of protection | Switchboards, control gear, motor starters | Generators | Motors | Transformers, semiconductor converters | Lighting fixtures | Heating appliances | Cooking appliances | Accessories (e.g. switches, connection boxes) |
| Dry accommodation spaces | Danger of touching live parts only | IP20 | × | – | × | × | × | × | × | × |
| Dry control rooms | | | × | – | × | × | × | × | × | × |
| Control rooms | Danger of dripping water and/or moderate mechanical damage | IP22 | × | – | × | × | × | × | × | × |
| Engine and boiler rooms above floor plates | | | × | × | × | × | × | × | × | IP44 |
| Steering gear rooms | | | × | × | × | × | × | × | – | IP44 |
| Refrigerating machinery rooms (excluding ammonia plants) | | | × | – | × | × | × | × | – | IP44 |
| Emergency machinery rooms | | | × | × | × | × | × | × | – | IP44 |
| General storage rooms | | | × | – | × | × | × | × | – | × |
| Pantries | | | × | – | × | × | × | × | × | IP44 |
| Provision rooms | | | × | – | × | × | × | × | – | × |
| Bathrooms and showers | Increased danger of water and/or mechanical damage | IP34 | – | – | – | – | × | IP44 | – | IP55 |
| Engine and boiler rooms below floor plates | | | – | – | IP44 | – | × | IP44 | – | IP55 |
| Closed fuel oil separator rooms | | | IP44 | – | IP44 | – | × | IP44 | – | IP55 |
| Closed lube oil separator rooms | | | IP44 | – | IP44 | – | × | IP44 | – | IP55 |
| Ballast pump rooms | Increased danger of water and mechanical damage | IP44 | × | – | × | × | IP34 | × | – | IP55 |
| Refrigerated rooms | | | – | – | × | – | IP34 | × | – | IP55 |
| Galleys and laundries | | | × | – | × | × | IP34 | × | × | × |
| Shaft or pipe tunnels in double bottom | Danger of water spraying, presence of cargo dust, serious mechanical damage, aggressive fumes | IP55 | × | – | × | × | × | × | – | IP56 |
| Holds for dry cargo | | | – | – | – | – | × | – | – | × |

| (1) | (2) | (3) | (4) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Equipment | | | | | | | |
| Location | Condition of location | Degree of protection | Switchboards, control gear, motor starters | Generators | Motors | Transformers, semiconductor converters | Lighting fixtures | Heating appliances | Cooking appliances | Accessories (e.g. switches, connection boxes) |
| Open decks | Danger of water ingress in massive quantities | IP56 | × | – | × | – | IP55 | × | – | × |

Notes: ① "×" means that the requirements of column (3) are to be complied with, or if impossible, the requirements of note ② are to be satisfied; "–" means that such equipment is generally not to be installed.

② Where the protection is not achieved by the equipment itself, other means are to be taken or the condition of the location for installing the equipment is to be improved to ensure the degree of protection required in the Table.

③ Where electrical equipment is installed in areas where explosive dusts may be present, the requirements of 1.3.3.7 of this Section are to be complied with.

④ Where the main and emergency switchboards are constructed and installed in accordance with the requirements of Section 3 of Chapter 3, PART FOUR in CCS Rules for Classification of Sea-going Steel Ships and Sections 1 and 2 of Chapter 2 of this PART respectively, the requirements of this Table may be dispensed with.

1.3.2.3 Where fixed water-based local fire-fighting systems are installed in the engine room, the degrees of protection of electrical and electronic equipment are to meet the requirements of 1.3.2.3 and 1.3.2.4 in PART FOUR of CCS Rules for Classification of Sea-going Steel Ships.

### 1.3.3 Explosion protection

1.3.3.1 Where electrical equipment is installed in areas where explosive gas or vapour atmospheres may be present, it is to be of a certified safe type complying with the following requirements:

(1) The construction and type testing of the safe type electrical equipment is to be in accordance with the relevant acceptable standards①.

(2) The safe type electrical equipment is to be certified by a competent testing authority.

1.3.3.2 The certified safe type equipment normally used on board ships includes the following types of protection:

(1) Intrinsically safe Ex "i";
(2) Flameproof Ex "d";
(3) Increased safety Ex "e";
(4) Pressurized enclosure Ex "p";
(5) Special protection Ex "s";
(6) Powder filled Ex "q";
(7) Encapsulated Ex "m".

1.3.3.3 The electrical equipment allowed to be fitted in spaces subject to an explosion hazard, e.g. battery rooms, lamp stores and paint lockers (including ventilation ducts), is to comply with the following requirements:

(1) The electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services. Such equipment is to be of a certified safe type listed in 1.3.3.2(1) to (5) of this Section. For other spaces, the electrical equipment of certified safe types listed in 1.3.3.2 of this Section may be fitted, and the explosion groups and temperature classes of such equipment are at least to comply with the requirements in Table 1.3.3.3.

(2) Cables (through runs or terminating cables) of armoured type or installed in metallic conduits are to be used.

(3) The switches, protective devices and motor control gear for the electrical equipment installed in such spaces are to interrupt all poles or phases and preferably are to be located in non-hazardous spaces.

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① Refer to IEC publication 60079: Electrical Apparatus for Explosive Gas Atmospheres, or an equivalent national standard. e.g., GB 3836: Electrical Apparatus for Explosive Gas Atmospheres.

In addition, the relevant requirements for paint locker ventilation openings, battery rooms, oil tankers and ships carrying vehicles with fuel in their tanks for their own propulsion are given in 1.3.3.4, 1.3.3.5 of this Section, and Sections 11, 16 and 17 of Chapter 2.

**Explosion Group and Temperature Class** **Table 1.3.3.3**

| Location | Group① | Temperature class① |
|---|---|---|
| Battery rooms | II C② | T1 |
| Paint lockers | II B | T3 |
| Lamp stores | II A | T3 |
| Ammonia plant rooms③ | II A | T1 |
| Acetylene storage rooms | II C | T2 |
| Spaces carrying dangerous goods | According to the category of dangerous goods carried | According to the category of dangerous goods carried |
| Tunnels for pipes containing oil with a flash point of 60℃ or below | II A | T3 |

Notes: ① The explosion groups and temperature classes of electrical equipment listed in this Table and hereinafter in this PART are according to the relevant requirements of IEC Publication 60079: Electrical Apparatus for Explosive Gas Atmospheres or of GB 3836: Electrical Apparatus for Explosive Atmospheres.

② Explosion groups II A, II B and II C of electrical equipment listed in this PART are applicable only to intrinsically safe apparatus and flame-proof apparatus. For other types of explosion-proof electrical equipment, Group II is to be used.

③ Electrical equipment installed in R717 refrigerator room is to comply with the requirements in Section 5 of Chapter 2 of PART FIVE of the CCS Rules for Classification of Sea-going Steel Ships.

1.3.3.4 In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets of the paint locker, the following electrical equipment may be installed:

(1) certified safe type equipment listed in 1.3.3.2(1) to (5) of this Section, while cables and their installation are to comply with the requirements of 1.3.3.3(2);

(2) explosion-proof equipment of non-sparking construction (Ex “n”);

(3) appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature;

(4) appliances with simplified pressurized enclosures or vapour-proof enclosures (minimum degree of protection IP55) whose surface does not reach unacceptably high temperature.

1.3.3.5 The enclosed spaces giving access to the paint locker may be considered as non-hazardous, provided that:

(1) the door to the paint locker or the door of the paint locker is a gastight door with self-closing devices (a watertight door may be regarded as a gastight door) without holding back arrangements;

(2) the paint locker is provided with an acceptable, independent, natural ventilation system ventilated from a safe area;

(3) warning notices are fitted adjacent to the paint locker entrance stating that the locker contains flammable liquids.

1.3.3.6 Socket outlets are, unless expressly specified otherwise, not to be installed in spaces subject to an explosion hazard.

1.3.3.7 Where electrical equipment is to be installed in areas where explosive dusts may be deposited, it is to comply with the following requirements:

(1) the degree of protection by enclosures is to be at least IP55;

(2) the maximum surface temperature of the equipment in continuous service is to be at least 75 K lower than the glow temperature of a 5 mm thick layer of the dust.

### 1.3.4 Earthing

1.3.4.1 All accessible metal parts of the electrical equipment, other than current-carrying ones, are to be earthed, except for:

(1) lamp caps;

(2) shades, reflectors and guards supported on lamp holders or lighting fittings constructed of, or shrouded in, non-conducting material;

(3) metal parts on, or screws in or through, non-conducting material, which are separated by such material from current-carrying parts and from earthed non-current-carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;

(4) portable appliances having double and/or reinforced insulation, provided that the appliances conform

with recognized safety requirements;
(5) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(6) clips for fluorescent lamps;
(7) apparatus supplied at a working voltage not more than 50 V. For the alternating current, this voltage is a value of root mean square. Autotransformers are not to be used for the purpose of achieving this voltage;
(8) cable clips.

1.3.4.2 When the electrical equipment is directly fixed on the metal hull of the ship or securely fixed on bedplates (or supports) which have a good electrical contact with the metal hull of the ship, a special earthing conductor may not be required.

1.3.4.3 Whether the earthing is achieved through a special conductor or by bedplates (or supports) of the equipment, the surfaces in contact are to be clean, flat and bright so as to ensure an effective contact, and measures are to be taken to prevent the connection from loosening and corrosion.

1.3.4.4 When special earthing conductors are used, they are to be of copper or other corrosion-resistant materials of good conductivity, and are to be protected against mechanical damage and corrosion where necessary. The nominal cross-sectional area of various copper earthing conductors is not to be less than required in Table 1.3.4.4.

1.3.4.5 Bare metal parts of movable or portable appliances, other than current-carrying ones, are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket outlet, and the cross-sectional area of the earth conductor is to comply with the requirements of Table 1.3.4.4.

**Size of Earthing Conductors** **Table 1.3.4.4**

| Type of earthing conductor | Cross-sectional area of associated current-carrying conductor $S$ (mm$^2$) | Minimum cross-sectional area of copper earthing conductor $Q$ (mm$^2$) |
|---|---|---|
| Earth-continuity conductor in flexible cable or flexible cord | $S \leq 16$ | $Q = S$ |
| | $S > 16$ | $Q = S/2$, but at least 16 |
| Earth-continuity conductor incorporated in fixed cable | $S \leq 16$ | $Q = S$, but at least 1.5 |
| | $S > 16$ | $Q = S/2$, but at least 16 |
| Special fixed earthing conductor | $S \leq 2.5$ | $Q = S$, but at least 1.5 |
| | $2.5 < S \leq 120$ | $Q = S/2$, but at least 4 |
| | $S > 120$ | $Q = 70$ |

1.3.4.6 Metal coverings (braid or armour) of cables are to be effectively earthed at both ends of the run, except that final sub-circuits may be earthed at the supply end only. This does not necessarily apply to control and instrumentation cables or intrinsically safe circuit cables where single point earthing is permitted for technical or safety reasons.

1.3.4.7 The metal coverings of cables may be earthed by one of the means described below:
(1) gripped by metal clamps and connected to the metal hull of the ship by dedicated copper earthing conductors. The relationship between the cross-sectional area of the copper earthing conductors and the cross-sectional area of the current-carrying conductors of the cables is to comply with Table 2 in IEC 60092-352 or as follows:

$$Q \geq 1.5 \text{ mm}^2, \text{ for } S \leq 25 \text{ mm}^2;$$
$$Q \geq 4 \text{ mm}^2, \quad \text{for } S > 25 \text{ mm}^2;$$

(2) by means of glands intended for this purpose and so designed as to ensure an effective earth connection;
(3) by means of clamps or clips of corrosion-resistant metal, enabling a good contact between the metal coverings of cables and the earthed metal.

1.3.4.8 The electrical continuity of metal coverings of cables is to be ensured throughout the length of the cables, particularly at joints and tappings.

1.3.4.9 Every connection of an earth-continuity conductor or a special earthing conductor to the hull structure is to be made in an accessible position, and is to be secured by a screw of brass or other corrosion-resistant material and having a diameter not less than 4 mm, which is to be used for this purpose only.

1.3.4.10 Where aluminium superstructures are secured to the steel hull of a ship with an insulation to prevent electrolytic corrosion between these materials, a separate bonding connection is to be provided between the superstructure and the hull which is to be made in such a manner that electrolytic corrosion is prevented and the connection points may readily be inspected.

1.3.4.11 In order to avoid the hazard of an incentive discharge due to the build-up of static electricity resulting from the flow of liquids/gases/vapours, all cargo tanks, process plants and piping systems that

contain flammable liquids, evolve combustible gases and/or develop flammable dusts are to comply with the following requirements:
(1) The resistance between the above cargo tanks, process plants and piping systems and the hull of the ship is not to be greater than 1 MΩ.
(2) The requirements of 1.3.4.11(1) will be readily met without the use of bonding straps where cargo tanks, process plants and piping systems are directly or via their supports, either welded or bolted to the hull of the ship.
(3) Bonding straps are required for cargo tanks, process plants and piping systems which are not permanently connected to the hull of the ship, e.g.:
① independent cargo tanks;
② cargo tanks and piping systems which are electrically separated from the hull of the ship;
③ pipe connections arranged for the removal of spool pieces;
④ wafer-style valves with non-conductive (e.g. PTFE) gaskets or seals.
(4) Where bonding straps are required, they are to be:
① clearly visible so that any shortcomings can be clearly detected;
② designed and sited so that they are protected against mechanical damage and that they are not affected by high resistivity contamination, e.g. corrosive products or paint;
③ easy to install and replace.
(5) Bonding straps are to be made of copper or other corrosion-resistant materials of good conductivity, having a cross-sectional area of at least 10 $mm^2$.

### 1.3.5 Electromagnetic compatibility

1.3.5.1 Appropriate measures are to be taken to reduce the interference due to electromagnetic energy so that all electrical and electronic equipment can operate normally in a ship's electromagnetic environment.
1.3.5.2 The allowable value of the voltage (current) of the interference induced by electrical and electronic equipment and the means of interference suppression are to comply with the relevant provisions of acceptable standards①.

### 1.3.6 Visual and audible signals

1.3.6.1 Except those required in 1.3.6.2 of this Section, the colour of visual signals is to comply with the requirements of Table 1.3.6.1.
1.3.6.2 Except those required above, the visual and audible signals are to comply with the acceptable regulations or standards②.

**Colours of Visual signals** **Table 1.3.6.1**

| Colour | Meaning | Explanation | Example |
|---|---|---|---|
| Red | Danger or alarm | Warning of danger or a situation which requires immediate action | Operation failure of essential services;<br>Temperature or pressure of water, oil etc. reaching a critical value;<br>Power failure of essential circuits |
| Yellow | Caution | Change or impending change of conditions | Temperature or pressure is abnormal, but not reaching a critical value |
| Green | Safety (normal operating or normal working conditions) | Indication of a safe situation | Normal operation of machinery;<br>Normal circulation of liquids;<br>Pressure, temperature and currents within limits |
| Blue | Instruction/information (specific meaning assigned according to the need in the case considered) | Blue may be given a meaning which is not covered by the three above colours: red, yellow and green | Motor begins to start;<br>Unloading generator begins to switch on;<br>Heating circuit of stopping motor is connected |
| White | No specific meaning assigned | Any meaning, may be used if red, yellow or green is considered not applicable | Earthing insulation indication;<br>Synchronizing lamp;<br>Telephone calling;<br>Automated equipment |

### 1.3.7 Harmonic Distortion for Ship Electrical Distribution System including Harmonic Filters③

① Refer to IEC Publication 60533: Electromagnetic Compatibility of Electrical and Electronic Installations in Ships, or corresponding standards.
② Refer to Code on Alerts and Indicators, 2009 adopted by IMO resolution A.1021(26).
③ Applicable to ships with the contract construction date of July 1st, 2017 and after and ships with the retrofit of harmonic filters dated on or after July 1st, 2017.

1.3.7.1 Ships where harmonic filters are installed on main busbars of electrical distribution system are to meet the requirements of 1.3.7.2 to 1.3.7.6 below. However, harmonic filters installed for single application frequency drives such as pump motors and harmonic filters installed for enhancing electromagnetic compatibility of single equipment/system may be excluded from these requirements.

1.3.7.2 The total harmonic distortion (THD) of electrical distribution systems is not to exceed 8%. This limit may be exceeded where all installed equipment and systems have been designed for a higher specified limit and the harmonic distortion calculation report is to be provided and made available on board as a reference for the surveyor at annual survey.

1.3.7.3 Ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar as well as alerting the crew should the level of harmonic distortion exceed the acceptable limits. Where the engine room is provided with automation systems, this reading is to be logged electronically, otherwise it is to be recorded in the engine log book for future inspection by the surveyor.

1.3.7.4 The system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced. The system integrator of the distribution system is to provide the ship owner with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters. The calculation results and validity of the guidance provided are to be verified by the surveyor during sea trials.

1.3.7.5 A harmonic filter is to be arranged as a three-phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter. Additionally, a current unbalance detection system independent of the overcurrent protection alerting the crew in case of current unbalance is to be installed. This alarm is to be provided locally and/or in normally attended spaces.

1.3.7.6 Consideration is to be given to additional protection for the individual capacitor element (e.g. relief valve or overpressure disconnector) in order to protect against damage from rupturing. This consideration is to take into account the type of capacitors used.

# CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

## Section 1 MAIN SOURCE OF ELECTRICAL POWER

### 2.1.1 Generating sets

2.1.1.1 A main source of electrical power having sufficient capacity to supply all services mentioned in 1.1.1.4(1) of this PART is to be provided. Unless otherwise specified in 2.1.1.2 of this Section, the main source of electrical power is to be composed of at least two generator sets.

2.1.1.2 The main source of electrical power of ships navigating in the sheltered areas or their equivalent service areas is to meet the following requirements:

(1) At least one generating set is to be provided for cargo ships.

(2) Where various auxiliary engines serving the main engine, steering oil pumps, fire pumps and bilge pumps in passenger ships are driven by the main engine, at least one generator set is to be provided.

2.1.1.3 Unless otherwise specified in 2.1.1.2 of this Section, the number and capacity of these generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety of the ship . Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water. The comfortable conditions of habitability may not be complied with for cargo ships of less than 500 gross tonnage.

2.1.1.4 For all passenger ships and cargo ships of more than 500 gross tonnage navigating in open sea service area and greater coastal service area, as well as all passenger ships navigating in coastal service area, the generating sets are to be such as to ensure that with any one generator or its prime mover out of operation, the remaining generating sets are still capable of providing the electric services necessary to start the main propulsion plant from a dead ship condition.

2.1.1.5 Where the main source of electrical power is necessary for propulsion and steering of the ship, the continuity of the power supply to the equipment necessary for the propulsion and steering and for ensuring the safety of the ship is to comply with the following requirements:

(1) Where the electrical power is normally supplied by more than one generating set simultaneously in parallel operation, means of protection, including automatic shedding (see 2.5.7.1 of this PART) of non-essential services and if necessary, automatic shedding of the arrangements for habitability and secondary essential services, are to be provided to ensure that in case of loss of any of these generating sets, the remaining ones are kept in operation to supply equipment necessary for propulsion and steering and for ensuring the safety of the ship.

(2) For the ships with the total capacity of main generating engines more than 500kVA, where the electrical power is normally supplied by one generator, provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of a stand-by generator(s) of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of the stand-by generator is to be as rapid as possible, preferably within 30 s, but in any case not more than 45 s, after loss of power.

2.1.1.6 For all passenger ships and cargo ships of 500 gross tonnage and above, where the main source of electrical power is necessary for propulsion of the ship, the main bus-bar is to be subdivided into at least two independent sections which are normally be connected by a circuit breaker without tripping mechanism or disconnecting link or switch by which the bus-bar can be split easily. So far as is practicable, the connection of generating sets and other duplicated equipment is to be equally divided between the sections.

2.1.1.7 A common power plant may be provided as both the main source of electrical power and the electrical power for propulsion, and in this case the requirements of Section 15 of this Chapter are to be complied with.

2.1.1.8 The alternating current system is to be such that with one generating set out of action, the remaining sets have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any other device to fail due to excessive voltage drop on the system. Motors which have a very large capacity and are not essential to the safe navigation of the ship, such as thruster motors, may be started when all generators are put into operation without causing any essential services to stop.

2.1.1.9 The arrangement of the ship’s main source of electrical power is to be such that the operation of the services referred to in 1.1.1.4(1) of this PART can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.1.1.10 For calculation of the capacity of generating sets, where the detailed power of refrigerated

containers can not be provided, it is recommended that 11 kW be taken for each socket where the sockets of refrigerated containers are adaptable to power supply for 20 ft or 40 ft containers. It is also recommended that 7.5 kW be taken for each socket suitable only for power supply of 20 ft containers. A diversity factor of 0.6 may be taken for calculation of loading of containers.

2.1.1.11 A main source of electrical power may be provided as necessary for non-self-propelled ships. Where the main source of electrical power is the generator, the provisions of 2.1.1.1 to 2.1.1.9 of this Chapter need not be complied with.

### 2.1.2 Generators driven by main propulsion machinery (e.g. shaft-driven generators)

2.1.2.1 A generator driven by the ship's main propulsion machinery may be considered part of the ship's main source of electrical power, provided that:

(1) the generator is capable of operating normally under all weather conditions during sailing or maneuvering, also when the vessel is stopped, within the specified limits for the voltage variation in relevant requirements of Chapter 3, PART FOUR in CCS Rules for Classification of Sea-going Steel Ships and for the frequency variation in 1.2.2.2 of this PART;

(2) the rated capacity of the generator and/or generating systems is in compliance with 2.1.1.3 upon loss of any other generator in service;

(3) the short circuit current of the generator and/or generating system is sufficient to trip the generator circuit breaker, taking into account the selectivity of the protective devices for the distribution system. Protection is to be arranged in order to safeguard the generator in case of a short circuit in the main bus-bar. The generator is to be suitable for further use after fault clearance;

(4) the automatic start of standby sets is in compliance with 2.1.1.5(2).

2.1.2.2 A generators and/or generating system driven by the ship's propulsion machinery and not forming part of the ship's main source of electrical power may be used, whilst the ship is at sea, to supply the electrical equipment necessary for normal operational and habitable conditions provided that:

(1) sufficient and adequately rated additional generators are fitted, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section;

(2) arrangements are fitted to automatically start at least one of the generators, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section, in compliance with 2.1.1.5(2), when frequency variations exceed the limits specified below:

Frequency variations (permanent): ±5.5%

Frequency variations (transient): ±11% (5 s);

(3) voltage variations are within the limits specified in relevant requirements of Chapter 3, PART FOUR in CCS Rules for Classification of Sea-going Steel Ships and frequency variations within the limits specified in 1.2.2.2;

(4) the short circuit current of the generator and/or generating system is sufficient to trip the generator and/or generating system circuit breaker, taking into account the selectivity of the protective devices for the distribution system;

(5) automatic load shedding arrangements are fitted in accordance with the requirements of 2.5.7;

(6) on ships having remote control of the propulsion machinery from the navigation bridge, means are provided or procedures are in place to ensure that the power supply to essential services is maintained during maneuvering conditions in order to avoid a blackout situation.

### 2.1.3 Transformers

2.1.3.1 Except for cargo ships navigating in sheltered areas or their equivalent service areas, the number, capacity and arrangement of transformers are to meet the following requirements if they constitute the necessary parts of main electric power source system and lighting system as required in 2.1.1.1 of this Section.

(1) The transformers are to be such that, with any one transformer out of operation, the remaining transformers are sufficient to ensure the safe operation of the equipment necessary for normal propulsion and for safety of the ship.(2) Each transformer is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides.

(3) Each primary circuit is to be provided with switch gear and protection devices in each phase.

(4) Each of the secondary circuits is to be provided with a multi-pole isolating switch.

### 2.1.4 Installation of switchboards

2.1.4.1 The main switchboard is to be so placed relative to the main power plant that, as far as is practicable, the integrity of the normal electrical supply will be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery

control room situated within the main boundaries of the space, is not to be considered as separating the switchboard from the generators. Cargo ships of less than 500 gross tonnage may not to meet this requirement.
2.1.4.2 Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the switchboard. If this is unavoidable, suitable protection is to be provided in these positions.
2.1.4.3 Passages of an adequate width are to be left in front of and behind switchboards. The width of the front passage is to be at least 0.8 m. The width of passage behind the switch gear is to be at least 0.6 m, and at least 0.5 m at frames. If the construction of a switchboard is such as to permit maintenance, inspection and replacement of parts from the front or from the ends, the passageway behind the switchboard may be dispensed with.
2.1.4.4 Where the length of the main switchboard is greater than 4 m, passageways are to be, as far as possible, provided at both ends of the switchboard. Except that the main switchboard is installed in the machinery control room, doors with locking devices are to be provided at entrance of the passageway behind the switchboard.
2.1.4.5 The passageways in front of and behind the main switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

### 2.1.5 Automatic connecting and disconnecting of main generating set

2.1.5.1 Requirements of paragraph 2.1.5.2 to 2.1.5.6 are to be met where start, stop and load sharing between generators, is controlled by an automation system.
2.1.5.2 The following alarms are to be arranged:
(1) variations in bus bar voltage from the rated value (high and low);
(2) variations in bus bar frequency from the rated value (high and low);
(3) automatic load shedding;
(4) failure in automatic switch-on of circuit breaker of generator;
(5) automatic tripping of circuit breaker of generator;
(6) failure in load distribution (with the necessary time delay, see 3.2.8.5 of Chapter 3, PART FOUR in the CCS Rules for Classification of Sea-going Steel Ships for the percentage of load distribution).
2.1.5.3 Means are to be provided to avoid two or more than two generating sets being switched on the common bus-bar of main switchboard simultaneously.
2.1.5.4 After a blackout due to short circuit, the generator circuit breaker is permitted to be switched on only once.
2.1.5.5 Where the standby generating set has been started as a result of a prolonged main bus-bar voltage or frequency fluctuation, the running generating set is to be stopped and disconnected from the switchboard prior to connection of the standby generating set.
2.1.5.6 Automatic starting attempts which fail are to be limited to restrict consumption of starting energy.

## Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

### 2.2.1 General requirements

2.2.1.1 Unless otherwise specified in 2.2.4 of this Section, all passenger ships and cargo ships of more than 500 gross tonnage are to be provided with emergency source of electrical power in compliance with the requirements of 2.2.1 to 2.2.3 in this Section.
2.2.1.2 The emergency source of electrical power is to be so arranged as to comply with the following:
(1) The emergency source of electrical power, associated transforming equipment (if any), transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and are to be readily accessible from the weather deck. They are not to be located forward of the collision bulkhead, except where permitted for cargo ships in exceptional circumstance.
(2) The location of the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment (if any), and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment (if any), and the main switchboard or in any machinery space of category A will not interfere with the supply, control and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency electrical power and the emergency switchboard is not to be continuous to the boundaries of machinery spaces of category A

or those spaces containing the main source of electrical power, associated transforming equipment (if any), or the main switchboard.

2.2.1.3 The emergency source of electrical power may be a generator, which is to comply with the following requirements:

(1) driven by a suitable prime mover with independent cooling system and supply of fuel as well as starting arrangements complying with the requirements of 9.5.3 of Chapter 9, PART THREE of the Rules;

(2) started automatically upon failure of the electrical supply from the main source of electrical power and connected automatically to the emergency switchboard, and those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section then transferred automatically to the emergency generating set, except for cargo ships fitted with a transitional source of emergency electrical power in accordance with 2.2.1.5 of this Section. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.

2.2.1.4 The emergency source of electrical power may also be an accumulator battery, which is to comply with the following requirements:

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(3) supplying those services (except as otherwise stated) referred to in 2.2.2.1 (for passenger ships) or 2.2.3.1 (for cargo ships) of this Section, and immediately supplying those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.5 Where the emergency source of electrical power is a generator, a transitional source of emergency electrical power which consists of an accumulator battery is to be provided in compliance with the following requirements, except for cargo ships fitted with an emergency generator capable of automatic starting in accordance with 2.2.1.3(2):

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) so arranged as to supply immediately and automatically in the event of failure of either the main or emergency source of electrical power those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.6 Where the emergency source of electrical power is required to restore propulsion from a dead ship condition, the capacity is to be sufficient to supply the following equipment:

(1) equipment referred to in 2.2.2.1(1) to 2.2.2.1(2)⑥ or 2.2.3.1(1) to 2.2.3.1(3)⑥ of this Section;

(2) restoring propulsion of the ship and operation of other machineries (as appropriate) from a dead ship condition.

2.2.1.7 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power and to comply with the following requirements:

(1) Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

(2) Where the emergency source of electrical power is an accumulator battery, the accumulator battery is not to be installed in the same space as the emergency switchboard.

(3) Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the emergency switchboard. If this is unavoidable, suitable protection is to be provided in these positions.

(4) The passageways in front of the emergency switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.2.1.8 An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or transitional source of emergency electrical power are being discharged.

2.2.1.9 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected according to the requirements of 2.5.9.6 and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

2.2.1.10 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power is to be available to the emergency circuits.

2.2.1.11 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits (also see 2.2.5).

2.1.1.12 The emergency source of electrical power provided onboard non-motorized ships is to meet the requirements of 2.2.4.

**2.2.2 Scope and period of supply of the emergency source in passenger ships**

2.2.2.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for the emergency lighting power supply in the following spaces, the power supply period of ships navigating in the greater coastal service area is 12h, and the power supply period of ships navigating in the coastal service area is 6h:

① at every muster and embarkation station and over the sides;

② in alleyways, stairways and exits giving access to the muster and embarkation stations;

③ in all escape routes with their stairways and exits (including angles and intersections) placed not more than 0.3 m above the deck (where an emergency source of electrical power is required for the supply);

④ in all service and accommodation alleyways, stairways and exits, personnel lift cars;

⑤ in public spaces and in cabins accommodating more than 16 persons;

⑥ in the machinery spaces and main generating stations including their control positions;

⑦ in all control stations, machinery control rooms, and at each main and emergency switchboard;

⑧ at all stowage positions for firemen's outfits;

⑨ at the steering gear; and

⑩ at the fire pump, the sprinkler pump and the emergency bilge pump as required in Chapter 2-2, PART FOUR of CCS existing Technical Regulations for Statutory Survey of Ships Engaged on Domestic Voyages (hereinafter called as Statutory Regulations for Domestic Ships) and at the starting position of their motors;

(2) for the power supply to the following equipment, the power supply period of ships navigating in the greater coastal service area is 12h, and the power supply period of ships navigating in the coastal service area is 6h:

① the navigation lights and other signal lights required in Chapter 8, PART FOUR in theexisting Statutory Regulations for Domestic Ships ;

② VHF radio equipment, MF radio installation (if any), ship earth station (if any) and MF/HF radio equipment (if any) required in Chapter 4, PART FOUR in the existing Statutory Regulations for Domestic Ships;

③ all internal communication equipment required in an emergency[①];

④ the navigational aids as required in Chapter 5, PART FOUR of the existing Statutory Regulations for Domestic Ships, where such provision is unreasonable or impracticable, ships of less than 5,000 gross tonnage may not to meet this requirement, subject to agreement;

⑤ the fire detection and fire alarm system, and the fire door holding and release system; and

⑥ for intermittent operation of the daylight signaling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarm system, alarms for warning of the release of extinguishing media);

⑦ One of the fire pumps as required in Chapter 2-2, PART FOUR of the existing Statutory Regulations for Domestic Ships;

⑧ Automatic sprinkler pump (if any);

⑨ Emergency bilge pump and all equipment essential for the operation of electrically powered remote controlled bilge valve;

unless such services mentioned above in ③ to ⑥ have an independent supply for the specified period from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9 of Chapter 3, PART FOUR in the CCS Rules for Classification of Sea-going Steel Ships suitably located for use in an emergency; If ventilation is provided according to IEC

[①] The internal communication equipment required in an emergency case is to include: (1) Important telephone system; (2) Emergency engine telegraph; (3) Public address system; (4) Communication in an emergency; (5) Communication facilities between the officer on duty and the crew responsible for closing the watertight door that cannot be closed from the central control station; (6) Communication facilities between the navigation bridge and the main fire control station.

Publication 62040 or other acceptable standards, the UPS device with valve regulated type battery may be placed in the same compartment with electrical equipment;

(3) for the period of time required in Chapter 13, PART THREE in the CCS Rules for Classification of Sea-going Steel Ships, the steering gear if required to be so supplied by that paragraph;

(4) for a period of half an hour:

① any watertight doors required in Chapter 2-1, PART FOUR of the Statutory Regulations for Domestic Ships to be power operated together with their indicators and warning signals;

② the emergency arrangements to bring the lift cars to deck level for the escape of persons (if provided).

2.2.2.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services, if they depend upon an electrical source for their operation:

(1) for half an hour:

① the lighting required in 2.2.2.1(1) (except for 2.2.2.1(1)③) and navigation lights and other signal lights required in 2.2.2.1(2)① of this Section;

② all services required in 2.2.2.1(2)③, ⑤ and ⑥ unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(2) power to operate the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided;

(3) power to the control, indication and alarm circuits for operation of watertight doors for half an hour.

2.2.2.3 In addition to the emergency lighting required above, passenger ships with ro-ro cargo spaces or special category spaces are to be provided with the following:

(1) all passenger public spaces and alleyways are to be provided with supplementary emergency lighting complying with the following:

① capable of operating for at least three hours when all other sources of electrical power have failed and under any condition of heel;

② the illumination provided is to be such that the approach to the means of escape can be readily seen;

③ the source of power for the supplementary lighting is to consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, other means of lighting which is at least as effective may be accepted by CCS;

④ the supplementary lighting is to be such that any failure of the lamp will be immediately apparent;

⑤ any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;

(2) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (1) above, is provided.

### 2.2.3 Scope and period of supply of the emergency source in cargo ships

2.2.3.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 3 h, emergency lighting at every muster and embarkation station and over the sides as required in Chapter 3, PART FOUR in the existing Statutory Regulations for Domestic Ships;

(2) for the emergency lighting power supply in the following spaces, the power supply period of ships navigating in the greater coastal service area is 6h, and the power supply period of ships navigating in the coastal service area is 3h:

① in all alleyways, stairways and exits;

② in the machinery spaces and main generating stations including their control positions;

③ in all control stations, machinery control rooms, and at each main and emergency switchboard;

④ at all stowage positions for firemen's outfits;

⑤ at the steering gear;

⑥ in all cargo pump rooms of tankers constructed on July 1st, 2002 and after;

(3) for the power supply to the following equipment, the power supply period of ships navigating in the greater coastal service area is 6h, and the power supply period of ships navigating in the coastal service

area is 3h:

① the navigation lights and other signal lights required in Chapter 8, PART FOUR of the existing Statutory Regulations for Domestic Ships;

② VHF radio installation, MF radio installation (if any), ship earth station (if any) and MF/HF radio installation (if any) required in Chapter 4, PART FOUR of the existing Statutory Regulations for Domestic Ships;

③ all internal communication equipment as required in an emergency[①];

④ the navigational aids for ships of 5,000 gross tonnage and above as required in Chapter 5, PART FOUR in the existing Statutory Regulations for Domestic Ships;

⑤ the fire detection and fire alarm system;

⑥ intermittent operation of the daylight signaling lamp, the ships whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarms system, alarms for warning of the release of extinguishing media, etc.);

⑦ One of the fire pumps as required in Chapter 2-2, PART FOUR of the existing Statutory Regulations for Domestic Ships;

unless such services mentioned above in ③ to ⑥ have an independent supply for the specified period from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9 of Chapter 3, PART FOUR in CCS Rules for Classification of Sea-going Steel Ships suitably located for use in an emergency; If ventilation is provided according to IEC Publication 62040 or other acceptable standards, the UPS device with valve regulated type battery may be placed in the same compartment with electrical equipment;

(4) for the specified period required in Chapter 13, PART THREE in the CCS Rules for Classification of Sea-going Steel Ships, the steering gear where it is required to be so supplied by that paragraph;

2.2.3.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services for half an hour, if they depend upon an electrical source for their operation:

(1) the lighting required in 2.2.3.1(1) and (2), and navigation lights and other signal lights required in 2.2.3.1(3)①. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(2) all services required in 2.2.3.1(3)③, ⑤and ⑥, unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

**2.2.4 Emergency source of electrical power in cargo ships of less than 500 gross tonnage and ships navigating in sheltered areas or their equivalent service areas**

2.2.4.1 The emergency source of electrical power complying with the requirements of 2.2.1 and 2.2.2 in this Section (for passenger ships) or 2.2.1 and 2.2.3 in this Section (for cargo ships) may be provided for cargo ships of less than 500 gross tonnage and ships navigating in sheltered areas or their equivalent service areas, and the accumulator battery sets complying with the following requirements may also provided as the emergency source of electrical power:

(1) located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;

(2) complying with the requirements of 2.2.1.4(1), (2) and 2.2.1.7 of this Section;

(3) capable of providing immediately power supply for any equipment as required in 2.2.4.2 of this Section.

2.2.4.2 The capacity of emergency source of electrical power is to be sufficient to supply the following equipment for at least 3h:

(1) lighting at muster and embarkation stations and over the sides, in all alleyways, stairways and exists, main switchboard, emergency power source and control stations;

(2) lighting in compartments accommodating more than 16 persons;

(3) navigation lights and other signal lights as required in Chapter 8, PART FOUR in the existing Statutory Regulations for Domestic Ships;

(4) Internal communication equipment and internal signal equipment used in an emergency case (such as: general emergency alarm system, etc.);

(5) fire detection and fire alarm system (if any);

(6) daylight signalling lamp, the ship's whistle and the manually operated call points (if any);

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[①] The internal communication equipment required in an emergency case is to include: (1) Important telephone system; (2) Emergency engine telegraph; (3) Public address system; (4) Communication in an emergency.

(7) radio communication onboard.

**2.2.5 Use of emergency generator in port**

2.2.5.1 The emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements below are complied with:

(1) to prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation;

(2) the prime mover is to be fitted with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation;

(3) the fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in 2.2.2 or 2.2.3 of this Section;

(4) the prime mover is to be designed and built for continuous operation and to be subjected to an examined and approved maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea;

(5) fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed;

(6) means are to be provided to readily change over to emergency operation;

(7) control, monitoring and supply circuits, for the purpose of the use of the emergency generator in port, are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services. When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits;

(8) instructions, which are to contain information on required fuel oil tank level, position of harbor/sea mode switch, ventilation openings etc., are to be provided on board to ensure that when the vessel is under way all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard. These instructions are to be posted in the emergency generator room.

# Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER

**2.3.1 Shore connection system of rated voltage of 1 kV and less**

2.3.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box complying with the requirements of 3.3.2.11 of PART FOUR in the CCS Rules for Classification of Sea-going Steel Ships is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source. Suitable cables having adequate ratings, permanently fixed, are to be provided for connection between the shore connection box and the main switchboard or emergency switchboard.

2.3.1.2 When a three-phase AC system with neutral earthed is adopted for shore and/or ship power, an earth terminal is to be provided for connecting the ship's hull to shore. In the case of DC systems with hull return, the negative terminal of the shore power must be connected to hull.

2.3.1.3 The shore connection is to be provided with an indicator at the main switchboard or emergency switchboard in order to show when the cables are energized.

2.3.1.4 Where an automatic control device is used for the connection and disconnection of shore supply, the device is to comply with the applicable requirements in Chapter 2 of PART SEVEN of the CCS Rules for Classification of Sea-going Steel Ships.

2.3.1.5 In addition to the requirements of 2.3.1.6, an interlocking device between all main generators and emergency generators and the shore supply is to be provided to avoid simultaneous power supply.

2.3.1.6 Where the system has the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.5.3, 19.2.5.4 and 19.2.6, Chapter 19 of PART EIGHT are to be complied with.

**2.3.2 Shore connection system of rated voltage above 1 kV**

2.3.2.1 For the shore connection system where load transfer between the shore supply and ship power is executed via blackout, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4, 19.2.5.2 and 19.2.6 of Chapter 19, PART EIGHT in the CCS Rules for Classification of Sea-going Steel Ships are at least to be complied with.

2.3.2.2 For the shore connection system having the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4,

19.2.5.3, 19.2.5.4 and 19.2.6 of Chapter 19, PART EIGHT of the CCS Rules for Classification of Sea-going Steel Ships are at least to be complied with.
2.3.2.3 The shore supply equipment installed onboard the ship is to comply with the requirements of Section 3, Chapter 19, PART EIGHT of the CCS Rules for Classification of Sea-going Steel Ships.

# Section 4 POWER SUPPLY AND DISTRIBUTION

### 2.4.1 Power supply and distribution systems

2.4.1.1 The following systems of distribution may be used:
(1) DC
two-wire insulated system;
two-wire system with negative pole earthed;
single-wire system with negative to hull return.
(2) AC single phase
two-wire insulated system;
two-wire system with one pole earthed;
single-wire system with hull return.
(3) Three-phase AC
three-wire insulated system;
four-wire system with neutral earthed;
three-wire system with neutral earthed and the hull serving as neutral wire.
three-phase four-wire insulated system may be used for ships of less than 500 gross tonnage.
2.4.1.2 For power supply and distribution systems for high-voltage systems, refer to the requirements of 2.14.2.1 of this PART.
2.4.1.3 For the distribution systems of ships intended for the carriage of crude oil and petroleum products in bulk having a flash point (closed-cup test) below 60℃, refer to the requirements of 2.16.2.1 of this PART.

### 2.4.2 Insulated distribution systems

2.4.2.1 The neutrals of generating sets are not to be connected together in the insulated distribution system.
2.4.2.2 The insulated distribution systems for power, heating and lighting circuits, whether primary or secondary, are to be provided with a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication in case of abnormally low insulation values.
However, except for oil tankers and other ships carrying dangerous goods, ships of less than 1,600 gross tonnages may be provided with earthing indicators to replace the device capable of monitoring the insulation level and giving alarm.

### 2.4.3 Earthed and hull return systems of distribution

2.4.3.1 The hull return system of distribution is not to be used for power, heating or lighting in ships of 1,600 gross tonnage and upwards, but not excluding the following:
(1) impressed current cathodic protective systems;
(2) limited and locally earthed systems, provided that any possible resulting current will not directly flow through any hazardous areas;
(3) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable condition.
2.4.3.2 Where the hull return system is used, all final sub-circuits are to have all poles or phases insulated, the hull return being achieved by connecting to the hull one of the bus-bars of the distribution board from which they originate.
2.4.3.3 The earthed distribution system in a high-voltage system is to be in compliance with the relevant requirements of 2.14.2.1 of this PART.
2.4.3.4 The earthing conductors used in the hull return system are to be of the same cross-sectional area as the conductors in the insulated pole or phase, and bare conductors are not to be used.
2.4.3.5 Enclosures of equipment or their mounting bolts are not to be used as return conductors or connection to the conductors.
2.4.3.6 The cross-sectional area of earthing conductors which do not normally carry current in service is to be 50% of that of the current-carrying conductors, but not less than 1.5 $mm^2$.
2.4.3.7 The system earthing of earthed distribution systems is to be effected by means independent of any

earthing arrangements of non-current-carrying parts of the electrical equipment.

### 2.4.4 Voltage and frequency

2.4.4.1 The maximum voltages of AC distribution systems are not to exceed the values given in Table 2.4.4.1.

**Maximum Voltages of AC Distribution Systems** **Table 2.4.4.1**

| No. | Application | Max. voltage (V) |
|---|---|---|
| 1 | For power equipment permanently installed and connected by permanent wiring | 15,000 |
| 2 | (1) For heating and cooking equipment permanently installed and connected by permanent wiring, except space heaters.<br>(2) For portable equipment, which is not hand-held during operation, and with connection by socket outlet which incorporates an earth continuity conductor of a size in accordance with 1.3.4.5 of this PART | 1,000 |
| 3 | (1) For lighting permanently installed<br>(2) For socket outlets supplying the following (which are not specified in items 2 and 4 in the table):<br>① equipment with double insulation;<br>② equipment earthed by earth continuity conductors of a size in accordance with 1.3.4.5 of this PART | 250 |
| 4 | For socket outlets used in spaces where particular risks due to exposure and conductivity may exit:<br>(1) supplied with or without the use of isolating transformers;<br>(2) where a safety isolating transformer is used supplying one consuming device only.<br>Both wires of such systems are to be insulated from earth | 55①<br>250 |
| 5 | Instrumentation and control equipment② | 55③<br>250 |

Note: ① For socket outlets with rated voltage up to 24V, the maximum voltage is 55V.
② For the control voltage of distribution systems operating at a voltage above 500 V, see 2.4.4.2 of this Section.
③ For instrumentation and control equipment with rated voltage up to 48V, the maximum voltage is 55V.

2.4.4.2 For distribution systems operating at a voltage above 500 V, the control voltage is to be limited to 230 V, except where all control devices of the distribution systems operating at a voltage not exceeding 1000 V are enclosed in appropriate control boxes.

2.4.4.3 The standard frequency for AC distribution systems is to be 50 Hz or 60 Hz.

2.4.4.4 The maximum voltages of DC distribution systems are not to exceed the values given in Table 2.4.4.4.

**Maximum Voltages of DC Distribution Systems** **Table 2.4.4.4**

| No. | Application | Max. voltage (V) |
|---|---|---|
| 1 | Power equipment | 1500 |
| 2 | Cooking equipment, heating equipment, lighting and socket outlets | 500 |
| 3 | Communication equipment, instrumentation | 250 |
| 4 | Socket outlets supplying power for life boats/rafts | 55 |

### 2.4.5 Balance of loads

2.4.5.1 For AC three-wire or four-wire systems, the electrical consumers are to be so grouped in the final sub-circuits that the load in each phase will, under normal conditions, be balanced as far as possible within 15% of its rated load at the individual distribution and section boards as well as the main switchboard.

### 2.4.6 Diversity factors

2.4.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.4.6.2 The diversity factor may be applied to the calculation of the cross-sectional area of conductors and the rating of switch gear and fuse gear.

2.4.6.3 For cargo winches, a diversity factor may be applied based on the information available from the manufacturer and the information agreed upon between the manufacturer and purchaser. If there is no exact information available, the diversity factors of Table 2.4.6.3 may be applied.

**Diversity Factors** **Table 2.4.6.3**

| Number of motors | Current to be provided for | |
|---|---|---|
| | Cases in which motors are of the same size | Cases in which motors are of different sizes |
| 2 | 100% of combined full load of motors | |
| 3 | 67% of combined full load of motors | 100% of full load of the largest motor + 50% of full load of each one of the other motors |
| 4 | 62% of combined full load of motors | |
| 5 | 60% of combined full load of motors | |
| 6 or more | 58% of combined full load of motors | |

**2.4.7 Power supply to essential services**

2.4.7.1 Unless expressly provided otherwise, the primary essential services are to be supplied directly from the main or emergency switchboard (if required), except for the total discrimination.

**2.4.8 Power supply to radio equipment and navigation equipment**

2.4.8.1 The power supply to the radio equipment as required in Chapter 4 and Chapter 5, PART FOUR in the existing Statutory Regulations for Domestic Ships (hereinafter referred to as the radio equipment) and the electrical/electronic navigation equipment as required in Chapter V (hereinafter referred to as the navigation equipment) of the SOLAS Convention are to comply with the requirements of 2.4.8.2 to 2.4.8.4.

2.4.8.2 Except the exemption required in Chapter 4 of the Statutory Regulations of Domestic Ships, the distribution board of supplies to the radio equipment is to be independent of that of supplies to the navigation equipment.

2.4.8.3 The distribution board of the radio equipment and that of the navigation equipment supplied by the emergency source of electrical power are to be supplied by separate feeders from main and emergency switchboards, and each distribution board is to be provided with a device for changing over between main and emergency sources of electrical power, which is in general to be initiated automatically. In the event of any failure of the power supply of the radio distribution board, an audible and visual alarm is to be given in the navigation bridge.

2.4.8.4 Each consumer is to be supplied by an independent final sub-circuit from its distribution board.

**2.4.9 Power supply to auxiliary machinery motors, etc.**

2.4.9.1 In addition to the above-mentioned requirements, the power supply to auxiliary machinery motors, illumination, navigation lights, internal communication systems and safety system for ships and persons on board is to comply with the relevant requirements of this PART.

2.4.9.2 For AC distribution systems, final sub-circuits rated over 16A are not to supply more than one equipment, except that they only supply socket outlets with current rating not greater than 32A.

**2.4.10 Sockets**

2.4.10.1 The sockets for general portable appliances are to be in compliance with the requirements of No.3 and No.4 in Table 2.4.4.1 of this Section.

2.4.10.2 For the sockets of distribution systems operating at different voltages and/or frequencies, non-interchangeable plugs are to be used for connection.

2.4.10.3 No socket outlets are to be provided below floor plates in machinery spaces, or in enclosed fuel and lubrication oil separator rooms.

2.4.10.4 Where sockets are necessary in cargo holds, they are to be fitted in positions with sufficient protection against mechanical damage.

2.4.10.5 For sockets of refrigerated containers, refer to the relevant requirements of Chapter 4, PART FIVE of the CCS Rules for Classification of Sea-going Steel Ships.

2.4.10.6 Socket outlets for power circuits rated over 16A (AC) or 10A (DC) are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

**2.4.11 Power supply with transformers operating in parallel**

2.4.11.1 Transformers arranged for parallel operation are to comply with the following requirements:

(1) their winding connections are to be compatible;

(2) their rated voltage ratios are to be equal (with tolerances within permissible limits);

(3) their short-circuit impedance values are to be equal (if expressed in percentage, a ratio within 0.9 to 1.1

may be allowed);
(4) when transformers are intended for operation in parallel, the rated output of the smallest transformer in the group is not to be less than 50% of the rated output of the largest transformer in the group.

**2.4.12 Power supply to safety, control and alarm systems of prime movers**

2.4.12.1 The prime movers referred to in this paragraph mean diesel engines, gas turbines and steam turbines, etc. that drive the electric generators which comprise the main source of electric power.

2.4.12.2 The safety, control and alarm systems of prime movers are to be supplied by two independent power sources, which and associated wiring are to be such that the requirements of 2.1.1.1(2) of this Chapter can be met in case of single failure.

**2.4.13 Power supply to electronic control system of diesel engines**

2.4.13.1 The power supply to electronic control systems of diesel engines is to comply with the requirements of 2.2.4 of Appendix 2 to Chapter 9, PART THREE of the CCS Rules for Classification of Sea-going Steel Ships.

# Section 5 PROTECTION

**2.5.1 General requirements**

2.5.1.1 Electrical installations are to be suitably protected against overcurrents including short circuits, and other electric faults. The performance and arrangement of the protective devices are to provide complete and coordinated automatic protection to ensure the continuity of supply to available essential services through the discriminative action of the protective devices in the event of a fault elsewhere, and to ensure the elimination of the effects of the fault to reduce damage to the system and hazard of fire.

Coordination is to be provided:

(1) between main generator protective device, main bus-bar section breakers (if provided with trip), protective devices (if fitted) of feeders connected to the main bus-bar, and protective devices of feeders from the main bus-bar;

(2) between protective devices of feeders and branch circuits of the distribution board containing essential services, unless otherwise specified in 2.5.3.6 of this Section;

(3) between protective devices of feeders from the emergency generator and the emergency bus-bar, and between protective devices of feeders interconnecting main and emergency switchboards and feeders from the emergency bus-bar.

2.5.1.2 Short-circuit protection is to be provided in each non-earthed pole or phase of distribution systems.

2.5.1.3 Overload protection is to be provided in:

(1) insulated two-wire DC or single-phase AC systems: at least one pole or phase;

(2) insulated three-phase AC systems: at least two phases;

(3) earthed systems: each non-earthed pole or phase.

2.5.1.4 No fuse or non-linked switch is to be inserted in an earthed conductor of distribution systems.

**2.5.2 Calculations of short-circuit current**

2.5.2.1 In the calculation of the maximum prospective short-circuit current, consideration is to be given to:

(1) all generators which are possibly connected in parallel to reach the maximum required power;

(2) all motors which are normally simultaneously connected in the system.

2.5.2.2 When necessary, the prospective short-circuit power factor of the AC system is to be calculated. If the power factor so obtained is less than the specified one corresponding to the rated short-circuit making or breaking capacity of the selected switch gear, then the breaking capacity of such switch gear is to be reduced accordingly.

2.5.2.3 Short-circuit calculations are to be referred to Appendix 1, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships, or performed by other acceptable methods.

2.5.2.4 In general, short-circuit calculations are to be carried out for the following:

(1) short circuit at the output terminal of generators;

(2) short circuit at the main bus-bar;

(3) short circuit at the bus-bars of the emergency switchboard, section switchboards and distribution switchboards;

(4) short circuit at the secondary side of power and lighting transformers.

For the determination of the discriminative action of protective devices, short-circuit calculations are, if necessary, to be additionally performed for short-circuit at terminals of the protected circuit, when only the smallest generator is in supply.

### 2.5.3 Choice of protective devices against short-circuit

2.5.3.1 Protection against short-circuit currents is to be provided by fuses or circuit-breakers.

2.5.3.2 Unless otherwise specified in 2.5.3.3 and 2.5.3.5, the breaking capacity of protective devices against short-circuit is to comply with the following requirements:

(1) The rated short-circuit breaking capacity of fuses and general circuit breakers is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.

(2) The rated operating short-circuit breaking capacity of circuit breakers for relevant circuits of essential services is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated operating short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.

2.5.3.3 The rated short-time withstanding current of category B circuit breakers (with short time-lag) is not to be less than the maximum prospective short-circuit current at the instant of contact separation at the point of installation. For the AC systems, the rated short-time withstanding current is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the instant of contact separation at the point of installation.

2.5.3.4 Unless otherwise stated in 2.5.3.5 of this Section, the rated short-circuit making capacity of every circuit breaker or switch which will possibly be initiated for a short-circuit is not to be less than the maximum peak value of the prospective short-circuit current at the point of installation.

2.5.3.5 The use of a circuit-breaker having a short-circuit breaking and/or making capacity less than the maximum prospective short-circuit current at the point of installation is permitted, provided that it is backed up on the generator side by a fuse or by a circuit-breaker (not the generator circuit-breaker) having the necessary rated short-circuit breaking/making capacity.

The short-circuit performance of the back-up protective arrangement is to be at least as that required for a single circuit-breaker by an acceptable standard[①] . The circuit-breaker is to have the same utilization category as the circuit-breaker on the load side of the back-up arrangement and a rated short-circuit breaking/making capacity for the maximum prospective short-circuit current at the supply terminal of the arrangement.

2.5.3.6 The back-up protection complying with the requirements of 2.5.3.5 may be used for circuits of non-essential services and of duplicated essential services with automatic change-over. The same fuse or circuit-breaker may be used to back up more than one circuit-breaker when essential services are not involved.

2.5.3.7 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuse and circuit-breaker are designed for coordinated action, so as to ensure that the operation of the fuse takes place in due time to prevent arcing between poles or between poles and metal parts of the circuit breaker when they are subjected to an overcurrent involving the operation of the fuse.

2.5.3.8 When determining the short-circuit performance requirements for the above-mentioned back-up protection arrangement, the impedance of the elements of the arrangement may be taken into account, such as the impedance of a cable connection when the circuit-breaker on the load side is far away from the back-up circuit-breaker or fuse.

### 2.5.4 Selective protection for short-circuit

2.5.4.1 Unless otherwise stated in 2.5.3.6 of this Section, the short-circuit protection of essential services is to be selective and comply with the following:

(1) to ensure that only the protective device nearest to the fault initiates disconnection of the defective circuit in the case of short-circuit;

(2) the tripping time of the protective devices connected in series is to be carefully coordinated;

(3) during the required time of selective protection, the protective device is to be capable of carrying the short-circuit current without breaking at the point of installation.

### 2.5.5 Choice of protective devices against overload

2.5.5.1 Circuit breakers provided for overload protection are to have a tripping characteristic (overcurrent

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① Refer to IEC Publication 60947-2: Low-Voltage Switch Gear and Control Gear – Part 2: Circuit-Breakers.

− trip time) adequate for the overloading ability of protected elements and for any discrimination requirement of the system.
2.5.5.2 The use of fuses for overload protection is permissible up to 320 A, provided they have suitable characteristics, but the use of circuit breakers or similar devices for protection against overload above 200 A is recommended.

### 2.5.6 Protection of generators

2.5.6.1 Unless otherwise provided in 2.5.6.8 of this section, generators are to be protected against short-circuit and overloads by circuit breakers arranged to interrupt simultaneously all insulated poles, and the overload protection is to be adequate for the thermal capacity of the generator. In addition, the following requirements are to be complied with:
(1) for overloads between 10% and 50%, the circuit breaker is to be tripped with a time delay of less than 2 min. It is recommended that the circuit breaker be set within the limits of 125 to 135% of the rated current of the generator and with a time delay of 15 to 30 s;
(2) for overcurrents in excess of 50% but less than the steady short-circuit current of the generator, the circuit breaker is to be tripped after a short-time delay required for the discriminative protection of the system.
It is recommended that the pick-up current for tripping of the circuit-breaker after a short-time delay be set at 200% to 250% of the rated current of the generator and with a maximum time delay of 0.2 s (DC) or 0.6 s (AC);
(3) circuit breakers for three or more generators connected in parallel are also to be provided with instantaneous releases which are to be set slightly greater than the maximum short-circuit current of the generators protected so that the circuit-breaker may break instantaneously. Other equivalent means may also be accepted subject to the agreement.
2.5.6.2 For generators less than 50 kW (or kVA) in unit capacity and not arranged to operate in parallel, a multi-pole linked switch with a fuse in each insulated pole may be fitted for protection.
2.5.6.3 Generators having a capacity of 1,500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit breaker will de-excite the generator and open the circuit breaker. This does not apply to emergency generators.
2.5.6.4 AC generators arranged to operate in parallel are to be provided with a reverse-power protection, with a time delay set within 3 to 10 s. DC generators arranged for parallel operation are to be provided with instantaneous or short-time delayed (less than one second) reverse current protection. The setting of reverse power (or reverse current) protection of generators arranged for parallel operation, dependent on the type of the prime mover used, is to be as follows:
(1) for diesel engines − 8% to 15% of the rated power (or current) of the generator;
(2) for steam turbines − 2% to 6% of the rated power (or current) of the generator.
A fall of 50% in the applied voltage is not to render the reverse power (or reverse current) protection inoperative, although it may alter the amount of reverse power required to open the breaker.
For the reverse-current protection, due consideration is to be given to the reverse current resulting from the ship's network (e.g. cargo winches).
Where equalizer leads are provided, the reverse current protection is to be connected to the positive pole of DC generators.
2.5.6.5 Generators arranged to operate in parallel are to be provided with undervoltage protection as follows:
(1) the operation of undervoltage release is to be instantaneous, if used to prevent the circuit-breaker from closing when the generator is not generating electrical energy;
(2) when the voltage drops down to 70% ~ 35% of the rated voltage, the undervoltage release is to operate with a time delay for discrimination purpose.
2.5.6.6 Where turbine-driven DC generating sets are arranged to operate in parallel, means are to be provided for the purpose of opening simultaneously all circuit-breakers of the generators when the overspeed tripping device of the driving turbine functions.
2.5.6.7 In the case of substantial reduction of speed of generators, the protective devices associated with generators are to remain effective.
2.5.6.8 Emergency generators are to be protected against short-circuit. Audible and visual alarm signals are to be given in the event of over-currents of emergency generators, which are not to lead to tripping of the circuit breakers of emergency generators.

### 2.5.7 Automatic load shedding

2.5.7.1 Proper load shedding or other equivalent arrangements are to be provided to automatically shed non-essential services, services for habitable conditions and where necessary, secondary essential services to ensure that the connected generator(s) is/are not overloaded. This load shedding may be carried out in one or more stages according to the overloading ability of the generator. In such case, the non-essential services are to be shed firstly.

### 2.5.8 Protection of power and lighting transformers

2.5.8.1 The primary windings of power and lighting transformers are to be protected against short-circuit and overload by multi-pole circuit-breakers or fuses. Overload protection may also be provided in the secondary windings.

2.5.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit breakers used for this purpose are to be capable of withstanding surge currents.

### 2.5.9 Protection of feeder circuits

2.5.9.1 Each feeder circuit is to be protected against overload and short circuits by a multi-pole circuit breaker arranged to interrupt simultaneously all insulated poles, or a multi-pole switch with fuses, but for a transitional emergency lighting feeder circuit it may also be accepted to use fuses only.

2.5.9.2 When a multi-pole switch with fuses is used, the following requirements are to be complied with:

(1) the fuse in the feeder sub-circuit from the main switchboard is to be fitted between the bus-bar and the switch;

(2) where the final sub-circuit from the distribution board has a rated current not exceeding 60 A and the consumers supplied by it can be disconnected at a nearby position, the switch may be omitted.

2.5.9.3 Circuits supplying consuming devices protected individually against overload (e.g. motors) may be provided with short-circuit protection only.

2.5.9.4 The protection of the steering gear circuits is to comply with the requirements of Chapter 13, PART THREE of the Rules.

2.5.9.5 Permanently fixed cables between the shore connection box and the main switchboard are to be protected by a circuit-breaker or an isolating switch and fuses. Such protection is to be fitted in the shore connection box.

2.5.9.6 In general, the interconnector feeder supplying the emergency switchboard from the main switchboard is to be protected at the main switchboard against overload and short-circuit. Where the system is allowed for reverse power supply, the interconnector feeder is to be additionally protected at the emergency switchboard at least against short-circuit.

### 2.5.10 Protection of motors

2.5.10.1 Motors rated at 1.0 kW or above and all motors for essential services are to be protected individually against overload and short-circuit, and against undervoltage as required in 2.5.10.6 of this Section. The short-circuit protection can be provided by the same protective device for both the motor and its supply cable.

2.5.10.2 Protection of steering gear motors is to comply with the requirements of Chapter 13, PART THREE of the Rules.

2.5.10.3 The protective devices are to be designed to allow the flow of currents during the normal accelerating period of motors under normal conditions of service. When the time-current characteristics of the overload protective device of a motor are not adequate for the starting period of the motor, the overload protecting device may be rendered inoperative during the accelerating period provided that the protection against short-circuit remains operative and that the suppression of the overload protection is only temporary.

2.5.10.4 For continuous duty motors, protective devices are to have a time delay characteristic which ensures reliable thermal protection of the motors for overload conditions. The maximum continuous current of the protective device is not to exceed 125% of the rated current of the protected motor.

2.5.10.5 For intermittent duty motors, the current setting and the delay characteristics for protective devices are to be chosen after considering the actual service condition.

2.5.10.6 Motors are to be provided with either:

(1) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted; or

(2) undervoltage release, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit, but so arranged that the motor restarts automatically and without excessive voltage drop or starting current on restoration of voltage.

The protective devices are to allow the motor to start when the voltage is above 85% of the rated voltage, and are without fail to intervene when the voltage is lower than approximately 20% of the rated voltage, at the rated frequency and with time delay when necessary.
2.5.10.7 When fuses are used to protect poly-phase motor circuits, consideration is to be given to protection against single phasing.

**2.5.11 Protection of lighting circuits**
2.5.11.1 Each lighting circuit is to be protected against overload and short-circuit.

**2.5.12 Protection of storage batteries**
2.5.12.1 Storage batteries, other than engine starting batteries, are to be protected against short-circuit with devices placed as near as practicable to the batteries.
2.5.12.2 Each battery charger is to be properly protected against discharging of the battery due to the reduction or loss of charging voltage.

**2.5.13 Protection of meters, pilot lamps and control circuits**
2.5.13.1 Voltmeters, voltage coils of measuring instruments, earthing indicators and pilot lamps together with their connecting leads are to be protected by fuses. A pilot lamp need not be individually protected provided the following conditions are satisfied:
(1) the pilot lamp is installed with the equipment in the same enclosure;
(2) the pilot lamp is supplied from the interior circuit of the enclosure of the equipment;
(3) the protection device in the circuit is rated less than 25 A;
(4) a fault in the pilot lamp would not jeopardize the supply to essential services.
2.5.13.2 The voltage coils of control and protective devices and equipment are to be protected by fuses. The coils themselves need not be protected provided the following conditions are satisfied:
(1) the coils are installed with the equipment in the same enclosure and protected by a general protective device;
(2) the coils are supplied from circuits of the equipment and the protective device of such circuits is rated less than 25 A.

**2.5.14 Protection of semiconductor equipment**
2.5.14.1 Semiconductor equipment is to be protected against overload and short circuit.

# Section 6 AUXILIARY MACHINERIES

**2.6.1 General requirements**
2.6.1.1 Motors rated at 1.0 kW or above and motors required for essential services are to be supplied from distribution boards by separate final sub-circuits.
2.6.1.2 Every electric motor is to be provided with efficient means of starting and stopping which are, in general, placed near the motor, so as to be easily operated by the person controlling the motor.
2.6.1.3 Means are to be provided for the disconnection of the full load from all live poles of supply of every motor rated at 0.5 kW or above and its control gear. Where the control gear is mounted on or adjacent to a main or other distribution switchboard, a disconnecting switch in the switchboard may be used for this purpose. Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.
2.6.1.4 When the starter or any other apparatus for disconnecting the motor is remote from the motor, it is required that either:
(1) provision be made for locking the circuit disconnecting in the OFF position; or
(2) an additional disconnecting-switch be fitted near the motor; or
(3) the fuse in each live pole or phase be so arranged that it can be readily removed and retained by an authorized person.
2.6.1.5 Where a single master-starter system (i.e. a starter used for controlling a number of motors successively) is used, undervoltage and over-current protection, means of isolation and a running indicator are to be provided for each motor, not less effective than those required for systems using a separate starter for each motor. Where the starter system is of an automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services, the starting portion is to be duplicated, and means are to be provided for change-over in the event of failure of one of the starters.

2.6.1.6 All motors with field adjustment for speed control are to be provided with a device which renders the motors to be started only when the field is fully excited.
2.6.1.7 The undervoltage, overload and short-circuit protection for motors are to comply with the requirements of Section 5, Chapter 2 of this PART.

**2.6.2 Steering gear**
2.6.2.1 Electrical or electrohydraulic steering gears are to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.

**2.6.3 Permanently installed submersible bilge pumps**
2.6.3.1 The motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard. The feeder cables are to be installed in continuous lengths from above the bulkhead to the motor terminals.
The cables are to be impervious-sheathed and armoured. Cables and their connections to such pumps are to be capable of operating under a head of water equal to the height of the bulkhead deck.
2.6.3.2 Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck. If an additional start-stop push button is provided near the motor, the circuits are to be so arranged as to ensure that all control circuits of the start-stop push button may be disconnected from the position above the bulkhead deck.
2.6.3.3 The power source of a permanently installed submersible bilge pump is also to comply with the relevant requirements of Section 5, Chapter 3, PART THREE of the Rules.

**2.6.4 Deck machinery**
2.6.4.1 Electromagnetic brakes for electrical deck machinery are to have, in addition, a hand release device.
2.6.4.2 If not otherwise specially required in their specifications, the duty of windlass motors and winch motors is to be rated for not less than 30 min.
2.6.4.3 Boat winch motors are to be provided with limit switches for cutting off the power supply upon returning of the boat to its original position.
2.6.4.4 The control device of boat winch motors is to be interlocked with the manual drive and manual brake.

**2.6.5 Fire safety equipment**
2.6.5.1 The electrical power supply to fire pump motors and fixed emergency fire pump motors, automatic sprinkler systems and water-spraying systems is to comply with the the existing statutory requirements.

**2.6.6 Stopping of ventilating fans and oil pumps**
2.6.6.1 Power ventilation of accommodation spaces, service spaces, cargo spaces and control stations is to be capable of being stopped from an easily accessible position outside the space being served. This position is not to be readily cut off in the event of a fire in the space served.
The exhaust fans in the exhaust ducts from galley ranges are to be capable of being shut off within the galley.
2.6.6.2 Stopping of the ventilation fans and oil pumps in machinery spaces
(1) The means provided for stopping the power ventilation serving the machinery spaces are to be grouped so as to be operable from two positions outside the space served, one of which is to be easily accessible and close to such space, and is not to be readily cut off in the event of a fire in the space served.
The means provided for stopping the power ventilation of the machinery spaces are to be entirely separate from the means provided for stopping ventilation of other spaces.
(2) Means of control are to be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). Except oil separators, such means of control are to be situated outside each related space so that it will not to be cut off in the event of a fire in the space served.
2.6.6.3 Additional requirements for passenger ships
(1) In passenger ships, the controls required in 2.6.6.2 of this Section are to be situated at one control position or grouped in as few positions as possible. Such positions are to have safe access from the open deck.
(2) In passenger ships carrying more than 36 passengers, power ventilation, except machinery space and cargo space ventilation and unless otherwise specified in the existing statutory regulations, is to be fitted

with controls so grouped that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.
Fans serving power ventilation systems to cargo spaces are to be capable of being stopped from a safe position outside such spaces.

### 2.6.7 Integrated cargo and ballast systems on tankers

2.6.7.1 The following requirements are applicable to integrated cargo and ballast systems on tankers.
2.6.7.2 An integrated cargo and ballast system means any integrated hydraulic and/or electric system used to simultaneously drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).
2.6.7.3 The operation of the cargo and/or ballast systems may be necessary, in certain emergencies or during navigation, to enhance the safety of the tanker, and measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system (including its control and safety systems).
2.6.7.4 The following design features are, inter alia, to be fitted:
(1) the emergency stop circuits of the cargo and ballast systems are to be independent from the circuits of the control systems. A single failure in the control system circuits or the emergency stop circuits is not to render the integrated cargo and ballast system inoperative;
(2) manual emergency stops of the cargo pumps are to be arranged in a way that they will not cause the stop of the power pack, rendering ballast pumps inoperable;
(3) the control systems are to be provided with backup power supply, which may be achieved by duplicated power supply from the main switch board. The failure of any power supply is to activate an audible and visual alarm at each location where the control panel is fitted;
(4) in the event of failure of an automatic or remote control system, a secondary means of control is to be available for the operation of the integrated cargo and ballast system. This may be achieved by manual overriding and/or redundancy control arrangements within the control system.

### 2.6.8 Vehicle ramp control system for ferries

2.6.8.1 The vehicle ramp control station is to be so arranged that the movement of the ramp can be observed by the operator.
2.6.8.2 An audible and visual alarm is to be given for power failure of the control system. At the same time, the ramp is to be kept at its position automatically. When the power supply is recovered, operation of the control mechanism is not to be continued until it its reset.
2.6.8.3 The indicator of ramp conditions is to be provided in the control station.
2.6.8.4 Devices for preventing control and driving circuits from action are to be provided under the following conditions:
(1) any of the covers is not taken off;
(2) enclosures of vehicles are not closed.
2.6.8.5 Audible and visual indications are to be given continuously at a conspicuous position by the ramp when the ramp is running.
2.6.8.6 Where the ramp is fixed by a retractable locking device, means are to be provided to ensure that the power will not be interrupted when the locking device is clutched and that no launching of the ramp is possible before the locking device is disengaged.
2.6.8.7 Where a ramp, in addition to that for the stern door, is provided for access from the wharf, its angle to the horizontal is to be less than 10° before the stern door is opened or closed.
2.6.8.8 The maximum inclination of the access ramp in operation to the horizontal is not to be more than the predetermined angle. An audible and visual alarm is to be given if the inclination exceeds the allowable angle.
2.6.8.9 Where a remote locking device is fitted, alternative means is to be provided for locking the ramp in case of failure of the locking control or locking mechanism.

## Section 7 LIGHTING AND NAVIGATION LIGHTS

### 2.7.1 General requirements

2.7.1.1 The lighting fittings fitted in cargo holds, exterior passageways, or other spaces where they are liable to mechanical damage, are to be provided with robust protective grids.
The lighting fittings located in such spaces where they are liable to considerable vibration are to be provided with means for damping the vibration.

Where lighting fittings are directly fixed on wooden panelling or other inflammable materials, precautions are to be taken against overheating and fire.
2.7.1.2 The switches of lighting fittings for baggage rooms, mail rooms, provisions rooms, refrigerated spaces and other similar spaces are not to be fitted inside such spaces, and are to be provided with a pilot lamp. Switches for lighting used in wet spaces and in spaces where the risk of explosion might arise are to be capable of isolating all insulated poles.
2.7.1.3 The warning signs showing "DANGER! HIGH VOLTAGE!" are to be provided in the spaces adjacent to discharge lamps operating at a voltage over 250 V and elsewhere as necessary.

### 2.7.2 Supply and control

2.7.2.1 The lighting point supplied by each final sub-circuit of rating of more than 16 A at the lighting distribution board is not to exceed one. The number of lighting points supplied by each final sub-circuit of rating 16 A or less at the lighting distribution board is not to exceed:
10 for circuits of rating 55 V or less;
14 for circuits of rating 56 ~ 120 V circuits;
24 for circuits of rating 121 ~ 250 V circuits.
In final sub-circuits for cornice lighting, panel lighting and electrical signs where lampholders are closely grouped, the number of points supplied is unrestricted provided that maximum operating current in the sub-circuit does not exceed 10 A.
Final sub-circuits for lighting are not to supply heating and power appliances, except for small galley equipment (e.g. toasters, mixers, coffee makers), small motors (e.g. of desk and cabin fans, refrigerators), wardrobe heaters and similar items.
2.7.2.2 The lighting for main engine rooms, large machinery spaces other than main engine rooms, large galleys, passageways (including accesses), stairways leading to boat decks, public spaces and berthing compartments accommodating more than 16 passengers is to be supplied by at least two final sub-circuits, and one of which may be the final sub-circuit for emergency lighting so that in the event of failure of any one of the sub-circuits the other one could still maintain the necessary lighting for such spaces. The lighting points for main engine and boiler rooms are to be distributed alternately.
For cargo ships, the compartments and spaces that lighting required to be powered by at least two final sub-circuits, may be reduced to the main engine room and boiler room, one of which may be the final sub-circuit of emergency illuminance.
2.7.2.3 Each main vertical fire zone is to be provided with at least two separate lighting feeders, one of which may be an emergency light feeder.
2.7.2.4 The permanently fixed lighting in cargo holds is to be controlled by switches located in a suitable position outside the cargo holds, capable of isolating all insulated poles and provided with a pilot lamp to indicate the power supply.
2.7.2.5 The degree of protection of lighting fittings located in various spaces in ships is to comply with the requirements of Table 1.3.2.2 of this PART. Lighting switches for spaces with special requirements are to be installed in accordance with the requirements of 2.7.1.2 of this Section.
2.7.2.6 Lighting circuits are to be provided with protection in accordance with the requirements of 2.5.11.1 of this Chapter.
2.7.2.7 A main electrical lighting system is to provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew, and is to be supplied from the main source of electrical power.
2.7.2.8 In assessing the current rating of lighting circuits, in case of lack of accurate information, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W. 200VA are to be counted for each lighting socket in accommodation spaces.

### 2.7.3 Emergency lighting

2.7.3.1 The arrangement of emergency lighting and the supplementary emergency lighting for ro-ro passenger ships are to comply with the relevant requirements of Section 2 of this Chapter.
2.7.3.2 In passenger ships, the means of escape, including stairways and exits, are to be marked by lighting or photo-luminescent strip indicators complying with acceptable standards① and placed not more than 0.3 m above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits.

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① Refer to the Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships adopted by IMO resolution A.752(18).

If electric illumination is used, it is to be supplied by the emergency source of power (see 2.2.2.1(1)③ of this Chapter).
2.7.3.3 All emergency lighting fittings are to be provided with a prominent mark or structurally different from other luminaries.
2.7.3.4 No local switch is to be installed in the transitional emergency lighting feeders.
2.7.3.5 No local switch is to be installed in the emergency lighting circuits in the spaces so specified in 2.2.2.1(1), 2.2.3.1(2) and 2.2.4.2 of this Chapter except for the emergency lights in the navigation bridge, at the stowage positions of lifeboats and life rafts.
2.7.3.6 Respective power sources of main and emergency switchboards, associated transforming equipment (if any), the main or emergency switchboard and lighting switchboard (excluding section board and distribution board) are not to be provided in the same space so that the two systems would not fail simultaneously in the event of a fire or other casualty in any space containing these appliances.
2.7.3.7 In passenger ships, supplementary lighting shall be provided in all cabins to clearly indicate the exit so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, shall automatically illuminate when power to the normal cabin lighting is lost and remain on for a minimum of 30 min.

### 2.7.4 Navigation lights
2.7.4.1 Each navigation light is to be supplied by a sub-circuit connected separately to the control box fitted at an easily accessible position on the navigation bridge and is to be controlled and protected in each insulated pole by a switch and a fuse or by a circuit breaker fitted in the control box.
2.7.4.2 The control box for navigation lights is to be supplied directly from the main switchboard and emergency switchboard. Where the transitional source of emergency power is provided according to Section 2 of this Chapter, the control box is to be supplied directly from the emergency switchboard and transitional emergency charging and discharging switchboard.
The control box for navigation lights in cargo ships of less than 500 gross tonnage and all ships navigating in sheltered areas or their equivalent service areas is to be supplied from the main switchboard and transitional emergency charging and discharging switchboard or emergency switchboard.
2.7.4.3 The change-over switch for the supply circuits required in 2.7.4.2 of this Section is to be installed on the control box or at a suitable position on the navigation bridge.
2.7.4.4 Each navigation light is to be provided with an automatic indicator giving an audible and visual indication of failure of the light. If a visual signal is used and connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal, and the audible and visual alarms for failure of the power source of the control box are to be provided. This requirement may be waived for the ships of less than 500 gross tonnage.
2.7.4.5 The power supply from the control box of navigation lights may be extended to the signal lights required in Chapter 8, PART FOUR in the existing Statutory Regulations for Domestic Ships, and other consumers are not to be connected to the box.

## Section 8 INTERNAL COMMUNICATION SYSTEMS

### 2.8.1 Main engine telegraph system
2.8.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propeller (hereinafter referred to as the normal control position of the propeller) are normally controlled. One of the means is to be the main engine telegraph system complying with the requirements of 2.8.1.2 of this Section.
2.8.1.2 The main engine telegraph system is to be in compliance with the following requirements:
(1) The controls of the transmitters and receivers are to be safeguarded by suitable means against being inadvertently moved.
(2) The engine telegraph is to be a two-way system in which the signal given by the receiver is also immediately discernible at the transmitter.
(3) In the case of installations with several control positions the acknowledged command must be indicated at all control positions. Where a control position is selected by switching, an additional indication is to be provided to show which one is in use.
(4) Both the transmitter and the receiver are to be equipped with a call-up device which remains in operation from the start of the command transmission till it is correctly acknowledged. The audible signal is

to be audible at any position in the engine room. If necessary, a visual signal is to be provided in addition to the audible signal.
(5) An audible alarm is to be provided for wrong direction of rotation of the main engine (applicable to reversible main engines) in the normal control position of the propeller.
(6) Power is to be supplied by the independent final sub-circuit and audible and visual alarms are to be provided on the navigation bridge for the purpose of indicating the failure of power supply.
2.8.1.3 The other means for communicating orders required in 2.8.1.1 may be an emergency engine telegraph system, the functions of which are to be in compliance with the requirements of 2.8.1.2(1) and (2), and which is to be supplied by the emergency power source.
2.8.1.4 A telephone system required in 2.8.2.2(4) may be fitted instead of the emergency engine telegraph system.

### 2.8.2 Important telephone systems

2.8.2.1 The important telephone systems are to be such as to ensure clear vocal intercommunication in all conditions of the ship.
2.8.2.2 The telephone system is to be provided in the following spaces:
(1) Bridge – Engine control room;
(2) Bridge – Steering gear control position in steering gear compartment;
(3) Bridge – Radio room, not required if communication can be made without telephone;
(4) Bridge – Normal control position of the propeller, not required if an emergency main engine telegraph system is provided;
(5) Bridge – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions;
(6) Engine control room – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions.
2.8.2.3 The telephone systems required in 2.8.2.2 are to be individual links, although a common telephone system may be used if it is ensured that the bridge can cut into existing conversations at all times.
2.8.2.4 The common telephone system described in 2.8.2.3 is to be an independent one and is allowed to provide voice communications, in addition to the spaces described in 2.8.2.2, only for those that are relevant to ship safety, such as the fire control station, $CO_2$ room and emergency generator room, etc.
2.8.2.5 Two-way calling equipment is to be provided for the telephone systems fitted in the engine room (except engine control room) and designed as being audible at any position in the engine room under full-power operation of the main propelling plant, and visual signals are to be provided in addition to the audible signals.
2.8.2.6 The important telephone system is to remain operable in case of failure of the main power supply.

### 2.8.3 Communication in an emergency

2.8.3.1 An intercommunication system is to be provided which enables commands to be transmitted between strategic positions, i.e. the emergency control station, the muster and embarkation station of survival craft and navigation bridge etc.
2.8.3.2 The communication system may comprise portable or permanently installed equipment, and is to remain operable in case of failure of the main power supply.

### 2.8.4 Engineers' alarms

2.8.4.1 An engineers' alarm is to be provided for all passenger ships and cargo ships of 500 gross tonnage and above to be operated from the engine room or engine control room and is to be clearly audible in the engineers' accommodation.
2.8.4.2 The audible alarm may be mounted centrally in the passageway of the engineers' accommodation, or individually in the cabins and the mess.
Where a decentralized arrangement is used, it is to be possible to transmit the alarm to the engineers both individually and collectively.

## Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD

### 2.9.1 General emergency alarms

2.9.1.1 In order to sound general emergency signals, a general emergency alarm system comprised of the ship's whistle or siren and additionally an electrically operated bell or klaxon or other equivalent apparatus, is to be provided on cargo ships of 500 gross tonnage and above and all passenger ships. Cargo ships of 500

gross tonnage and above may not be fitted with an independent general emergency alarm system when a public address system meeting the requirements of 2.9.2.1 (1) to (8) has already been provided.
In passenger ships, the alarm is to be capable of being given separately or simultaneously to crew and passengers.
Non-motorized ships manned with more than 12 persons are to be provided with a general emergency alarm system or a public address system in accordance with the requirements of 2.9.2.1 in this Section.
2.9.1.2 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle or siren, also from at least one other strategic points[①]. The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message from the public address system. For passenger ships there is also to be an additional activation point in the safety centre.
2.9.1.3 Where the general emergency alarm system is in operation, the acoustic system for entertainment is to be interrupted automatically.
2.9.1.4 The general alarm system is to be supplied from special feeders, being capable of automatically converting to the emergency source of electrical power in the event of failure of the main source of electrical power. In passenger ships, the system is also to be capable of being supplied by a temporary emergency source of electrical power.
2.9.1.5 The system is to be audible throughout all the accommodation and normal crew working spaces, including open decks in passenger ships.
The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB(A) and at least 10 dB(A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather. The sound pressure levels at the sleeping position in cabins and in cabin bathrooms are to be at least 75 dB(A) and at least 10 dB(A) above ambient noise levels.
2.9.1.6 Each electrically operated bell or klaxon or other equivalent warning system is to be separately protected against short circuit.

### 2.9.2 Public address system

2.9.2.1 Cargo ships of 500 gross tonnage and above are to be provided with a public address system in compliance with the following requirements:
(1) capable of broadcasting messages from the navigation bridge and fire control station etc. to all spaces where crew are normally present and muster stations;
(2) no operation required of receivers to accept the broadcast message;
(3) protected against unauthorized use;
(4) amplifiers have sufficient output power so that all loudspeakers for the purpose of emergency announcement can be operated at the same time;
(5) arranged to prevent feedback or any other interference;
(6) with the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:
① in interior spaces 75 dB(A) and at least 20 dB(A) above the speech interference level;
② in exterior spaces 80 dB(A) and at least 15 dB(A) above the speech interference level;
(7) capable of being supplied by both main and emergency power sources;
(8) if the public address system is used to give the general alarm, the following requirements are to be fulfilled:
① the performance requirements of 2.9.1 of this Section are to be complied with;
② at least two amplifiers are to be provided, each of them separately supplied;
③ the loudspeaker circuits are to be so arranged that an announcement at a reduced acoustic irradiation is maintained in the event of a failure of an amplifier or loudspeaker circuit;
④ where loudspeakers with built-in volume controls are used, the volume controls are to be disabled by the release of the alarm signal;
⑤ it is to be possible to transmit the clearly audible alarm signal at all times and other simultaneous signal transmissions are to be automatically interrupted;
⑥ an independent short-circuit protection is to be provided for each loudspeaker.
2.9.2.2 All passenger ships are to be provided with a public address system in compliance with the following requirements:
(1) capable of simultaneously broadcasting messages from bridge and central control station, etc. to all

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① Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

spaces where crew and passengers or both are normally present and muster stations, and capable of broadcasting messages to crew and passengers separately;
(2) complying with the requirements of 2.9.2.1(2) to (6);
(3) capable of interrupting at the control position on the navigation bridge any broadcast of the system from any other position onboard;
(4) the spaces where control units of the system are located are the control stations as defined in Chapter 2-2, PART FOUR in the Statutory Regulations for Domestic Ships, and each of the control stations is to be provided with the following emergency function controls:

① clearly indicating any emergency function;

② automatically overriding any other input system or programme;

③ automatically overriding all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces;

(5) at least two independent and separate amplifiers are to be provided, each of them separately supplied;
(6) at least two loudspeaker circuits connected to their respective amplifiers are to be installed in each fire zone, and their cables are to be laid as widely apart as practicable for their entire length;
(7) independent short-circuit protection is to be provided for each loudspeaker;
(8) capable of being supplied by main, emergency and temporary emergency sources of electrical power;
(9) if the public address system is used to give the general emergency alarm, the requirements of 2.9.1 of this Section are also to be complied with.

**2.9.3 Pre-discharge alarms of fixed fire extinguishing medium**

2.9.3.1 In any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches (except general cargo holds), and other spaces in which personnel normally work or to which they have access, which are protected by fixed gas fire-extinguishing systems, means are to be provided for automatically activating audible and visual alarms for the release of fire-extinguishing medium. The system is to be capable of operating in no case less than 20 s before the medium is released.

2.9.3.2 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces which are protected by fixed high-expansion foam fire-extinguishing systems are to be provided with audible and visual alarms for the release of fire-extinguishing medium in order to give warning of the release of the system. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.3 The above-mentioned alarm system is to be supplied by the emergency source of electrical power.

2.9.3.4 The the fixed fire-extinguishing system for the protection of machinery spaces where main propulsion engine and main generator set are located is to be designed such that any action other than the release of fire extinguishing media are not to lead to automatic shutdown of ventilation fans and oil pumps in these machinery spaces, such as opening the release box (cabinet) door during fire drills.

**2.9.4 Elevator alarms**

2.9.4.1 Elevators having an internal control are to be fitted with an emergency audible call-up device capable of being operated in the car and the alarm signal is to be transmitted to the positions where persons are normally present.

2.9.4.2 The emergency audible call-up device is to be independent from the power and control circuits of the elevator and supplied by the emergency source of electrical power.

**2.9.5 Alarms for closing refrigerated spaces**

2.9.5.1 Where the doors to refrigerated spaces such as refrigerated holds and refrigerating food chambers cannot be opened from the inside, an alarm capable of being activated within the spaces upon inadvertent closing of such doors is to be fitted and the alarm transmitted to normally manned positions.

**2.9.6 Fire detection and fire alarm systems**

2.9.6.1 The fire detection and fire alarm systems are to comply with the relevant requirements of Chapter 2-2, PART FOUR in the Statutory Regulations for Domestic Ships.

2.9.6.2 There are to be not less than two sources of power supply for the fixed fire detection and fire alarm system, one of which is to be an emergency source. The supply is to be provided by separate feeders reserved solely for that purpose. Such feeders are to run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

2.9.6.3 Operation of the automatic changeover switch or a failure of one of the power supplies is not to

result in permanent or temporary degradation of the fixed fire detection and fire alarm system.
2.9.6.4 Where the fixed fire detection and fire alarm system would be degraded by the momentary loss of power, a source of stored energy having adequate capacity is to be provided to ensure the continuous operation during changeover between power supplies.
2.9.6.5 Connection of electrical power supplies to an automatic changeover switch is to be arranged such that a fault will not result in the loss of all supplies to the automatic changeover switch.
2.9.6.6 The fixed fire detection and fire alarm system emergency power may be supplied by an accumulator battery. Where the system is supplied from an accumulator battery, the arrangements are to comply with the following requirements:
(1) The accumulator battery is to have the capacity to operate the fire detection system under normal and alarm conditions during the period required by 2.2.2 or 2.2.3 of this Chapter for the emergency source of power supply.
(2) The rating of the charge unit, on restoration of the input power, is to be sufficient to recharge the batteries while maintaining the output supply to the fire detection system.
(3) The batteries are to be located in or adjacent to the fire detection and fire alarm system control panel, or in another location suitable for use in emergency cases.(4) The feeders are to run from the accumulator battery or the accumulator battery charging and discharging board to the automatic changeover switch without passing through any other distributor.

### 2.9.7 Fire doors
2.9.7.1 The power, control, indication and alarm systems of fire doors complying with the existing statutory requirements are to be supplied by the emergency source of electrical power.
2.9.7.2 For Class I and II passenger ships[①], an indicator to show whether each door operated by remote control is opened or closed is to be provided in the normally manned control station.
2.9.7.3 For passenger ships, the control and indication systems for the fire doors are to be designed on the fail-safe principle, provided with a release system having manual reset capable of being operated from either side of the door.

### 2.9.8 Watertight doors in passenger ships
2.9.8.1 The power circuit and its associated control, indication and alarm circuits for power-operated sliding watertight doors are to be supplied either directly by the emergency switchboard or by a dedicated distribution board connected with the emergency switchboard above the bulkhead deck.
2.9.8.2 Where a motor is provided for the opening and closing of the watertight doors, unless an independent reserve energy is provided, the power source is to be capable of being automatically changed over to the transitional source of emergency electrical power in the event of failure of either the main or the emergency source of electrical power. The capacity of the motor is to be sufficient to operate the watertight door at least three times, i.e. closed – open – closed.
2.9.8.3 A single electrical failure in the operating or control system of a power-operated sliding watertight door is not result in a closed door opening or interrupt any manual operation of the watertight door.
2.9.8.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit as near as practicable to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console on the navigation bridge.
2.9.8.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a watertight door are not result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.
2.9.8.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water as follows:
(1) electric motors, associated circuits and control components: IPX7;
(2) door position indicators and associated circuit components: IPX8.
Where the water pressure testing is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 h;
(3) door movement warning signals: IPX6.
2.9.8.7 Electrical controls of watertight doors, including their cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted and so arranged as to minimize the likelihood of them being involved in any damage which the ship may sustain.

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[①] The classes of passenger ships, see Chapter 1, PART FOUR of the Statutory Regulations for Domestic Ships.

2.9.8.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least 5 s but not more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In passenger areas and areas where ambient noise level exceeds 85 dB(A), the audible alarm is to be supplemented by an intermittent visual signal.
2.9.8.9 The central operating console is to be fitted on the navigation bridge, having a "master mode" switch with the following two modes of control:
(1) "Local control" mode for normal use, which is to allow any door to be locally opened and locally closed after use without automatic closure; and
(2) "Door closed" mode for emergency use, which is to automatically close any door that is opened while still permitting any door to be opened locally but with automatic reclosure upon release of the local control mechanism.
2.9.8.10 The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door. Visual indicators showing whether the doors are open or closed are to be provided both on the central operating console and at hand operation positions above the bulkhead deck for watertight doors.
The indicating circuit is to be independent of the control circuit for each door.
2.9.8.11 It is not to be possible to remotely open any watertight door from the central operating console.

### 2.9.9 Watertight access doors and hatch covers, etc. in cargo ships

2.9.9.1 For sliding watertight doors provided to ensure the watertight integrity of internal openings which are used while at sea, their operation, control and indicators are to comply with the following requirements:
(1) capable of being closed remotely at the navigation bridge and operated at either side of the bulkhead;
(2) an indicator to show whether the door is open or closed is to be provided in the control position;
(3) audible and visual alarms are to be given as the door is closed;
(4) each power-operated door is to be provided with an individual hand-operated mechanism, and it is to be possible to open and close the door by hand from each side.
2.9.9.2 Access doors and hatch covers normally closed at sea to ensure the watertight integrity of internal openings are to be provided with means of indication showing locally and on the navigation bridge whether these doors or hatch covers are open or closed.
2.9.9.3 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, except for cargo hatch covers, are to be fitted with indicators on the navigation bridge to show whether the openings are open or closed.
2.9.9.4 The electrical power, control, indication and audible and visual alarms required in 2.9.9.1 are to remain operable in the event of the failure of the main source of electrical power.

### 2.9.10 Boundary doors of special category spaces and ro-ro spaces

2.9.10.1 The requirements below are applicable to boundary doors of special category spaces or ro-ro spaces as defined in Chapter 9, PART TWO of the Rules. These spaces may be flooded through the doors.
In cargo ships, where no part of a side shell door or stern door is under the highest waterline and the open area of the door is not greater than 6 $m^2$, the requirements from 2.9.10.2 to 2.9.10.5 of this Section are not applicable.
2.9.10.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their securing and locking devices are properly positioned.
The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator lights.
2.9.10.3 The indicator system is to be designed① on the fail-safe principle and is to show by a visual

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① The indicator system is considered designed on the fail-safe principal when the following are provided:
(1) The indication panel is provided with:
– a power failure alarm;
– an earth failure alarm;
– a lamp test;
– separate indication for door closed, door locked, door not closed and door not locked.
(2) Limit switch electrically closed when the door is closed (when more limit switches are provided, they may be connected in series).
(3) Limit switch electrically closed when securing arrangements are in place (when more limit switches are provided, they may be connected in series).
(4) Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked.
(5) In the case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in

alarm if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of electrical power or other secure power supply (e.g. UPS).
The sensors of the indicator system are to be protected from water, icing and mechanical damage.
2.9.10.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbor/sea voyage", so arranged that an audible alarm is given on the navigation bridge if the vessel leaves harbor with the bow door or inner door not closed or with any of the securing devices not in the correct position.
2.9.10.5 For side shell doors or stern doors, a water leakage detection system① with audible alarm and television surveillance is to be arranged on passenger ships to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. A water leakage detection system② with audible alarm is to be arranged on cargo ships to provide an indication to the navigation bridge.
2.9.10.6 For inner doors, a water leakage detection system② with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the doors.
2.9.10.7 Between the bow door and the inner door a television surveillance system② is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.
2.9.10.8 A drainage system② is to be arranged in the area between the bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system② is to be equipped with an audible alarm on the navigation bridge being set off when the water levels in these areas exceed 0.5 m or the high water level alarm threshold, whichever is lesser.
2.9.10.9 For ro-ro passenger ships, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means (e.g. television surveillance) so that any movement of vehicles in adverse weather conditions, or unauthorized access by passengers thereto, will be detected whilst the ship is underway.

# Section 10 HEATING AND COOKING EQUIPMENT

### 2.10.1 General requirements

2.10.1.1 All electric space heaters are to be installed permanently.
2.10.1.2 Heating appliances are not to be installed in positions where combustible gases and dusts are likely to accumulate.
2.10.1.3 Heating appliances are to be so mounted that there will be no risk of excessive heating of adjacent decks, bulkheads or other surroundings.

### 2.10.2 Control and installation of heating and cooking equipment

2.10.2.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters, a single-pole switch will be acceptable.

### 2.10.3 Supply of heating equipment

2.10.3.1 Each heater is to be connected to a separate final sub-circuit for heating except that up to ten small heaters of total connected current rating not exceeding 16 A may be connected to a single final sub-circuit for heating.

# Section 11 STORAGE BATTERIES

### 2.11.1 Arrangement and installation

2.11.1.1 Storage batteries are not to be installed in spaces where they are exposed to excessively high or low temperatures, water splattering, steam or other factors which will impair their serviceability or shorten

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place, as appropriate.
① The system is to be designed on the fail-safe principle, see footnote of 2.9.10.3 of this Section.

their service life. They are to be installed in such a way that persons will not be endangered and equipment will not be damaged by escaping gases or electrolytic leakage.

2.11.1.2 Storage batteries are to be so installed as to ensure accessibility for replacing cells, inspection, testing, topping-up and cleaning.

2.11.1.3 Storage batteries are not to be installed in the accommodation area. An exception may be granted for gastight cells, where charging does not result in the development of harmful gases.

2.11.1.4 Suitable protection measures are to be provided where the storage batteries are exposed to the risk of mechanical damage or falling objects.

2.11.1.5 Storage batteries connected to a charging device with a power output① of more than 2 kW are to be housed in a room assigned to the batteries only, or in a box or a locker on open deck.

2.11.1.6 Storage batteries connected to a charging device with a power output of 0.2 kW to 2 kW are to be installed in accordance with 2.11.1.5. They also may be installed in a box or a locker within a suitable space, or may be installed in an open position in a well ventilated machinery space.

2.11.1.7 Storage batteries connected to a charging device with a power output of less than 0.2 kW may be installed in an open position or in a battery box in any suitable space.

2.11.1.8 A gap of more than 20 mm is to be provided around each battery, and non-hygroscopic and electrolyte-resistant insulating material is to be used for the separation, dunnage and fixing of the battery. Measures are to be taken to prevent any leaking electrolyte from entering in contact with the ship's structure.

2.11.1.9 Any surface of dedicated battery rooms, boxes, lockers and associated ventilation ducts, etc., liable to corrosion, by the electrolyte or by the gas escaped from the electrolyte, are to be protected against corrosion.

2.11.1.10 Prime mover starter batteries are to be installed as close as practicable to the primer mover served.

2.11.1.11 Storage batteries used as emergency and temporary emergency source of electrical power are to be installed in accordance with the requirements of 2.2.1.2 of this PART.

2.11.1.12 A warning notice of "NO SMOKING OR NAKED LIGHTS" is to be displayed adjacent to doors of battery rooms and covers of battery boxes or lockers.

### 2.11.2 Ventilation

2.11.2.1 Battery rooms, boxes and lockers are to be ventilated to prevent the accumulation of flammable gases.

2.11.2.2 Natural ventilation may be employed if the required number of air changes is small and the duct can be run directly from the top of the battery room, box or locker to the open air above, with no part of the duct more than 45° from the vertical.

2.11.2.3 For natural ventilation of the battery room, the cross-sectional area $A$ of the inlet is to be equal to that of the outlet, not less than:

(1) for vented type batteries

$$A = \frac{50 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

(2) for valve-regulated sealed batteries

$$A = \frac{20 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

where: $U_n$ — nominal voltage of the battery, in V;

$Q$ — battery capacity, in Ah;

$n$ — number of cells in series.

2.11.2.4 Mechanical ventilation is to be provided for the battery room, box or locker containing vented type batteries with a total charging power higher than 2 kW.

2.11.2.5 Except those boxes and lockers on open deck or within the spaces required in 2.11.1.6 and 2.11.1.7 of this Section, the ventilation system for battery rooms, boxes or lockers is to be separate from other ventilating systems. The exhaust ducting is to be led to a location where any flammable gas can be safely diluted, away from any source of ignition, and the inlet ducting is to be led into spaces where flammable gases may accumulate. The outlet is to be situated at the top and the inlet at the bottom with the means to prevent the ingress of water and flame.

2.11.2.6 Mechanical ventilators for battery rooms, boxes or lockers are to be provided with means to prevent sparking in case of the impeller touching the casing. Non-metal impellers are to be of an antistatic

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① Power output of the charging device is to be calculated from the maximum charging current multiplied by the rated voltage of batteries.

material.
2.11.2.7 All openings of battery rooms, other than ventilation openings, are to be effectively sealed to prevent the explosive gas from entering adjacent compartments.
2.11.2.8 The quantity $Q$ of air expelled from the rooms, boxes or lockers containing vented type batteries is not to be less than:

$$Q = 0.11\ In \quad m^3/h$$

where: $I$ — the maximum charging current during the development of gas, but not less than 25% of the maximum charging current output by the charging device, in A;
$n$ — number of battery cells.
2.11.2.9 The quantity of air expelled from the rooms, boxes or lockers containing valve-regulated sealed batteries may be reduced to 25% of that required in 2.11.2.8.

### 2.11.3 Charging facilities
2.11.3.1 Charging facilities are to be provided for all storage batteries such that the completely discharged battery can be recharged to 80% of the rated capacity in not more than 10 h, having regard to the service requirements.
2.11.3.2 Suitable means are to be provided for controlling and monitoring charging of storage batteries, and to protect them in accordance with the requirements of 2.5.12.2 of this PART.
2.11.3.3 For floating circuits or any other conditions where the load is connected to the storage battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

### 2.11.4 Electrical equipment
2.11.4.1 The installation of electrical equipment is to be avoided in battery rooms. Where this is necessary, the certified explosion-proof electrical equipment required in 1.3.3.3 of this PART is to be selected.

### 2.11.5 Recording of the type, location and maintenance cycle of batteries
2.11.5.1 A schedule of batteries used for essential and emergency services is to be compiled and maintained. The schedule, which is to be reviewed, is to include at least the following information regarding the batteries:
— type and manufacturer's type designation;
— voltage and ampere-hour rating;
— location;
— equipment and/or system(s) served;
— maintenance/replacement cycle dates;
— date(s) of last maintenance and/or replacement;
— for replacement batteries in storage, the date of manufacture and shelf life.
2.11.5.2 Procedures are to be put in place to ensure that, where batteries are replaced, they are of an equivalent performance type.
2.11.5.3 Where valve-regulated sealed batteries are replaced by vented type batteries, it is to be ensured that there is adequate ventilation as so required in 2.11.2.4 and 2.11.2.8 of this Section, and that the requirements in 2.11.1 of this Section relevant to the location and installation of vented type batteries are complied with.
2.11.5.4 Details of the reviewed schedule and of the procedures, as mentioned above, are to be included in the ship's safety management system. Details of the schedule and of the procedures are to be integrated into the ship's operational maintenance routine as appropriate and be inspected at appropriate intervals, and to be verified by the surveyor.

## Section 12 CABLES

### 2.12.1 General requirements
2.12.1.1 Cables are to be selected according to the environmental conditions of the space where the cables will be installed, methods of installation, rated current, duty, diversity factor, etc.
2.12.1.2 The rated voltage of any cable is not to be lower than the nominal voltage of the circuit for which it is used.
2.12.1.3 Portable electrical equipment is to be provided with movable flexible cables.
2.12.1.4 Cables used in the non-earthing system are to be provided with suitable rating so as to sustain the additional stress of the cable insulation in the event of failure.

### 2.12.2 Choice of insulating material and voltage rating

2.12.2.1 The rated maximum operating temperature of the insulating material is to be at least 10℃ higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.12.2.2 The insulating material of cables is generally to be selected in accordance with Table 2.12.2.2. The selection of other insulating materials is to comply with IEC Publication 60092.

**Maximum Rated Conductor Temperature of Insulating Material Table 2.12.2.2**

| Insulating material | Abbrev. | Max. rated conductor temp. (℃) | |
|---|---|---|---|
| | | Normal operation | Short circuit |
| Ethylene propylene rubber | EPR | 90 | 250 |
| High modulus or hard grade ethylene propylene rubber | HEPR | 90 | 250 |
| Cross-linked polyethylene | XLPE | 90 | 250 |
| Silicone rubber | S95 | 95② | 350① |
| Cross-linked polyolefin material for halogen-free cables | HF90 | 90 | 250 |

Notes: ① Applicable only to power cables and not appropriate for tinned copper conductors.

② The maximum rated conductor temperature for silicone rubber is 180℃, but the practical maximum working temperature is limited by the sheathing materials.

2.12.2.3 The rated voltage of a cable is expressed in $U_0/U$, where $U_0$ is the rated power voltage between conductor and "earth" (or metallic screen or surrounding medium of cables) and $U$ is the rated power voltage between conductors. The choice of rated voltage of the cables depends on the system voltage and the system earthing arrangements, which is not to be lower than that given in Table 2.12.2.3.

**Choice of Rated Voltage of Cables for AC Systems Table 2.12.2.3**

| Rated (between phases) voltage (kV) of Systems | Rated voltage $U_0/U$ (kV) of cables | |
|---|---|---|
| | Category I distribution system | Category II distribution system |
| ≤0.25 | 0.15/0.25 | 0.15/0.25 |
| ≤1.0 | 0.6/1.0 | 0.6/1.0 |
| ≤3.0 (3.3) | 1.8/3.0 | 3.6/6.0 |
| ≤6.0 (6.6) | 3.6/6.0 | 6.0/10.0 |
| ≤10.0 (11) | 6.0/10.0 | 8.7/15.0 |

Notes:

① Category I distribution system: Protective devices are to be provided to automatically disconnect the circuits having earth faults.

② Category II distribution system: In AC insulation systems or in AC systems with high-resistance earthed neutral, circuits having earth faults are not to be automatically disconnected.

### 2.12.3 Choice of protective covering

2.12.3.1 Cables are to be provided with appropriate sheath that satisfies the fluid resistance requirements according to their installation locations. For example, cables permanently fitted on decks exposed to the weather, in bathrooms, cargo holds, refrigerated spaces, machinery spaces or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. The nature of the impervious sheath is to satisfy the requirements for environmental conditions.

2.12.3.2 When choosing different types of protective coverings, consideration is to be given to the mechanical actions to which each cable may be subjected during installation and in service. If the mechanical strength of the protective covering is considered insufficient, the cable is to be fitted in pipes or conduits or trunking or otherwise protected.

2.12.3.3 All cables and wiring external to electrical equipment are to be at least of a flame-retardant type. In general, cables which have passed the test of bunched flame-retardant cables in accordance with acceptable standards① are to be used. Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards② are to be bunched, means are to be

① Refer to IEC Publication 60332-3-22: Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A, or the equivalent standards.

② Refer to IEC Publication 60332-1-2: Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame and IEC Publication 60332-2-2: Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame, or the equivalent standards.

provided to limit the propagation of fire along the bunched cables (see 2.12.10).

2.12.3.4 Where cables for services, required to be operable under fire conditions, including their supply cables, pass through high fire risk areas①, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following:

(1) Cables being of a fire resistant type② complying with the requirements of 3.5.1.1 of PART Four in CCS Rules for Classification of Sea-going Steel Ships are installed and run continuously to keep the fire integrity within the high fire risk area, as shown in Figure 2.12.3.4.

(2) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

However, no requirements are provided for fail-safe system, system with self-test function or duplexed system with cable distributions running widely apart.

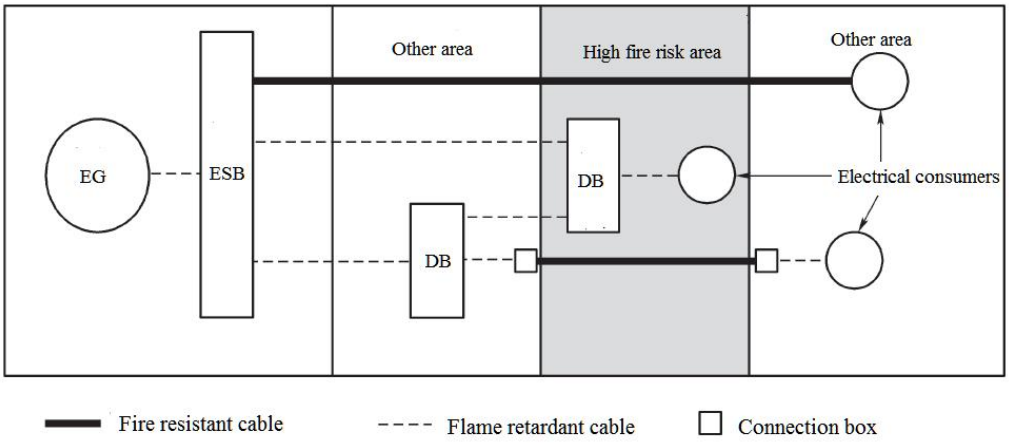



**Figure 2.12.3.4 Cables for Services under Fire Conditions**

2.12.3.5 Services required to be operable under fire conditions include:

(1) general emergency alarm system;

(2) fire detection and fire alarm system;

(3) fire extinguishing system and fire extinguishing medium release alarm;

(4) public address system;

(5) control and power systems of power operated fire doors and status indication systems for all fire doors;

(6) control and power systems of power operated watertight doors and their status indication systems;

(7) emergency lighting;

(8) low location lighting;

(9) remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion;

(10) emergency fire pump.

2.12.3.6 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and/or prime mover(s). When cables pass through high fire risk areas, the cables are to be of a fire resistant type.

2.12.3.7 Where necessary for particular applications, CCS may permit the use of special types of cables which do not comply with the requirements of 2.13.3.3 of this Section, such as radio frequency cables or digital computer information transmission system cables.

2.12.3.8 In passenger spaces and in service areas only halogen-free cables are to be used.

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① The "high fire risk areas" are defined as follows:

(1) machinery spaces as defined in SOLAS Reg. II-2/3.30, excluding spaces having little or no fire risk as defined in SOLAS Reg. II-2/9.2.2.3.2.2 (10) (including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510 );

(2) spaces containing fuel treatment equipment or other highly flammable substances;

(3) galley and pantries containing cooking appliances;

(4) laundry containing drying equipment;

(5) spaces as defined in SOLAS Reg. II-2/9.2.2.3.2.2(8), (12), and (14) for ships carrying more than 36 passengers.

② Fire resistant type cables are to be easily distinguishable.

### 2.12.4 Determination of the cross-sectional area of conductors

2.12.4.1 The maximum continuous load carried by a cable is not to exceed its current rating corrected by correction factors. The diversity factor of the individual loads and the duration of the maximum load may be taken into account in estimating the maximum continuous load.

2.12.4.2 Cables supplying cargo winches, revolving cranes, windlasses and capstans are to be suitably rated for their duty.

2.12.4.3 The cross-sectional area of the conductors of equalizer leads for DC generators is not to be less than 50% of that of the main circuit cables. The cross-sectional area of neutral conductors in three-phase four-wire distribution systems is to be equal to at least 50% of that of phase conductors. If the cross-sectional area of phase conductors is 16 $mm^2$ or less, the cross-sectional area of the neutral conductors is to be the same.

### 2.12.5 Continuous service current rating

2.12.5.1 The maximum continuous load carried by a cable is not to exceed the values as given in Table 2.12.5.1. Where a more precise evaluation of current rating has been carried out based on empirical or calculated data, details may be submitted to CCS for approval.

**Current Ratings for Cables during Continuous Working Time**
**(Based on Ambient Temperature of 45℃) (A)** **Table 2.12.5.1**

| Nominal cross-section | Maximum rated conductor temp 90℃ | | | Maximum rated conductor temp 95℃ | | |
|---|---|---|---|---|---|---|
| $mm^2$ | Single core | 2 cores | 3 or 4 cores | Single core | 2 cores | 3 or 4 cores |
| 1 | 18 | 15 | 13 | 20 | 17 | 14 |
| 1.5 | 23 | 20 | 16 | 26 | 22 | 18 |
| 2.5 | 30 | 26 | 21 | 32 | 27 | 22 |
| 4 | 40 | 34 | 28 | 43 | 37 | 30 |
| 6 | 52 | 44 | 36 | 55 | 47 | 39 |
| 10 | 72 | 61 | 50 | 76 | 65 | 53 |
| 16 | 96 | 82 | 67 | 102 | 87 | 71 |
| 25 | 127 | 108 | 89 | 135 | 115 | 95 |
| 35 | 157 | 133 | 110 | 166 | 141 | 116 |
| 50 | 196 | 167 | 137 | 208 | 177 | 146 |
| 70 | 242 | 206 | 169 | 256 | 218 | 179 |
| 95 | 293 | 249 | 205 | 310 | 264 | 217 |
| 120 | 339 | 288 | 237 | 359 | 305 | 251 |
| 150 | 389 | 331 | 272 | 412 | 350 | 288 |
| 185 | 444 | 377 | 311 | 470 | 400 | 329 |
| 240 | 522 | 444 | 365 | 553 | 470 | 387 |
| 300 | 601 | 511 | 421 | 636 | 541 | 445 |

2.12.5.2 The continuous service of cables required in this Section is the service that the continuous service period of current with constant loading are three times longer than the time constant of cables, i.e. more than the critical duration (see Figure 2.12.5.2).

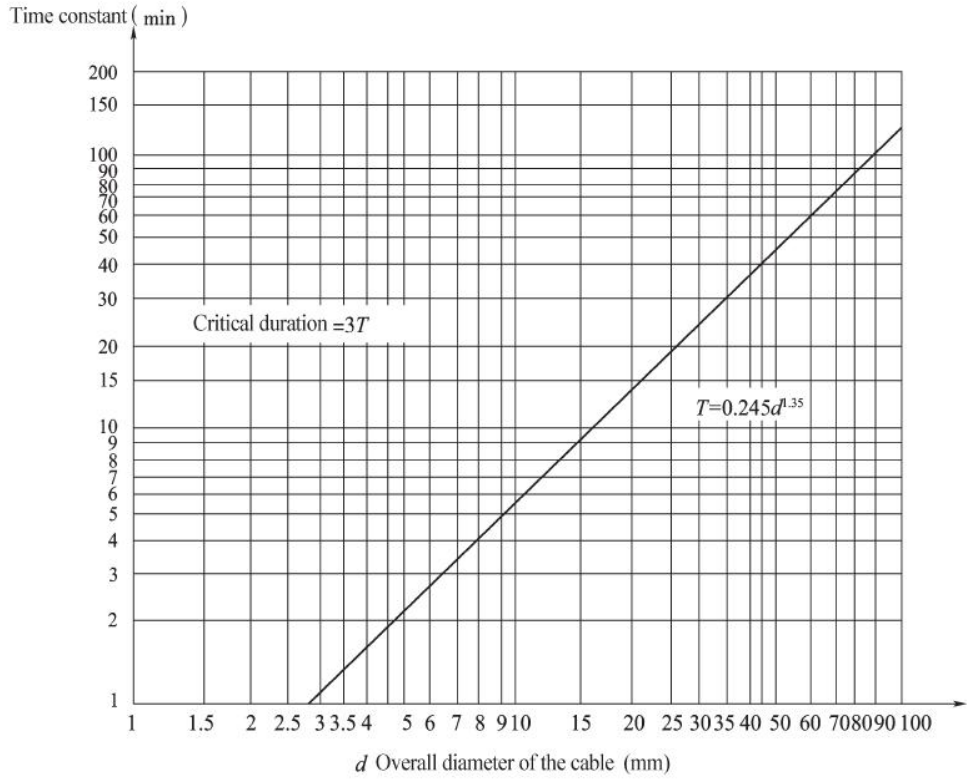



**Figure 2.12.5.2 Time Constant of Cables**

### 2.12.6 Correction factors for current rating

2.12.6.1 Correction factors for different ambient temperatures.

When it is known that the ambient temperature is different from 45℃, correction factors given in Table 2.12.6.1 are to be applied.

**Correction Factor for Ambient Temperature** **Table 2.12.6.1**

| Max. operating conductor temp. (℃) \ Ambient temp. (℃) | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 1.29 | 1.15 | 1.00 | 0.82 | – | – | – | – | – | – | – |
| 65 | 1.22 | 1.12 | 1.00 | 0.87 | 0.71 | – | – | – | – | – | – |
| 70 | 1.18 | 1.10 | 1.00 | 0.89 | 0.77 | 0.63 | – | – | – | – | – |
| 75 | 1.15 | 1.08 | 1.00 | 0.91 | 0.82 | 0.71 | 0.58 | – | – | – | – |
| 80 | 1.13 | 1.07 | 1.00 | 0.93 | 0.85 | 0.76 | 0.65 | 0.53 | – | – | – |
| 85 | 1.12 | 1.06 | 1.00 | 0.94 | 0.87 | 0.79 | 0.71 | 0.61 | 0.50 | – | – |
| 90 | 1.10 | 1.05 | 1.00 | 0.94 | 0.88 | 0.82 | 0.74 | 0.67 | 0.58 | 0.47 | – |
| 95 | 1.10 | 1.05 | 1.00 | 0.95 | 0.89 | 0.84 | 0.77 | 0.71 | 0.63 | 0.55 | 0.45 |

2.12.6.2 Correction factors for bunched cables

(1) For cables laid in one of the following manners and so arranged as to ensure free circulation of cooling air around each bunch, the current ratings in Table 2.12.5.1 may be directly applied:

① not more than six cables bunched together on cable trays, in cable conduits, pipes or trunking;

② more than six cables arranged in the following manners:

distance between any two sextuplets is at least equal to the diameter of the thickest cable

○○○○○○ ○○○○○○ ○○○○○○

or distance between any two triplets both horizontally and vertically is at least equal to the diameter of the thickest cable

○○○ ○○○ ○○○

○○○ ○○○ ○○○

(2) Where more than six cables, which may be expected to operate simultaneously at their rated capacity, are laid close together in a cable bunch[①] in such a way that there is an absence of free air circulation around

① Cables are said to be bunched when two or more are contained within a single conduit, trunking or duct, or if not enclosed, are not separated from each other.

them, a correction factor of 0.85 is to be applied. When a corrector factor of 0.85 is used, care is to be taken that there are in general not more than two layers in each cable bunch.

2.12.6.3 Correction factors for non-continuous service

(1) For half-hour and one-hour services, the corresponding correction factors given by Figure 2.12.6.3(1) may be applied. These correction factors are applicable only if the periods of no load are longer than the critical duration given in Figure 2.12.5.2.

(2) For repetitive short-time services, the corresponding correction factors given in Figure 2.12.6.3(2) may be applied.

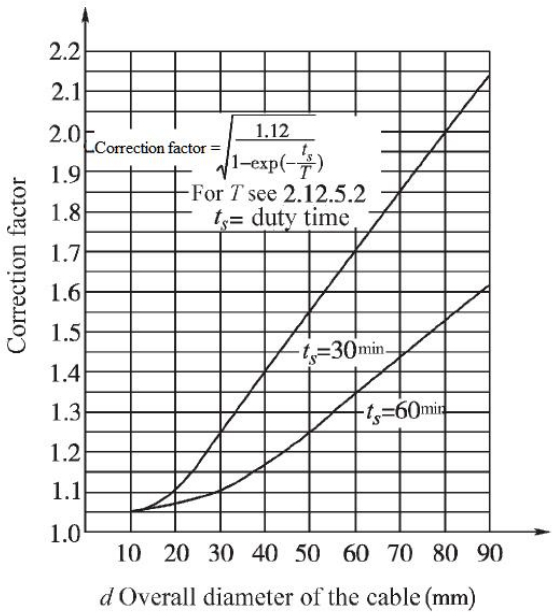
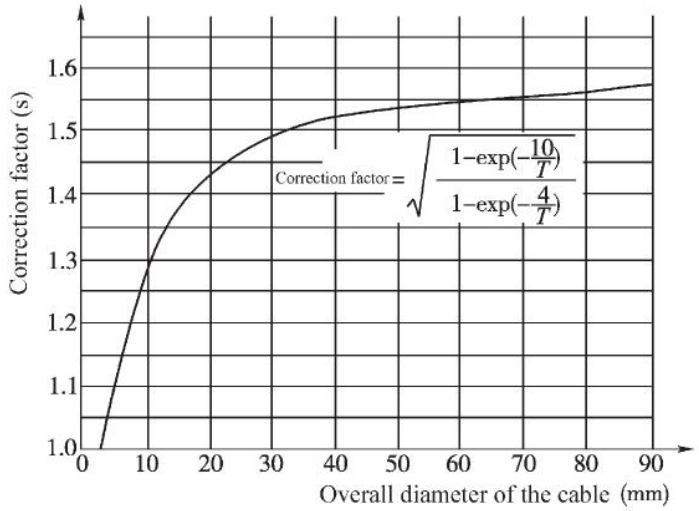



**Figure 2.12.6.3(1) Correction Factors for Half-Hour and One-Hour Services**




Note: The correction factors given in the Figure are roughly calculated for periods of 10 min, with a constant load for 4 min and without load for 6 min.

**Figure 2.12.6.3(2) Correction Factors for Repetitive Short-Time Services**

### 2.12.7 Parallel connection of cables

2.12.7.1 Parallel connection of cables will be permitted only for cables having a cross section of 10 $mm^2$ or more. The current rating of cables connected in parallel is the sum of the current ratings of all parallel conductors provided the cables have equal impedance, cross section and rated maximum operating conductor temperature.

### 2.12.8 Short-circuit capacity

2.12.8.1 Cables and their insulated conductors are to be capable of withstanding the mechanical and thermal effects of the maximum short-circuit.

### 2.12.9 Cable runs

2.12.9.1 Cable runs are to be, as far as possible, straight and accessible for inspection.

2.12.9.2 Cable runs are to be so arranged as to avoid the harmful effects from moisture or condensed water.

2.12.9.3 Cable runs are to be, as far as possible, away from the sources of heat such as boilers, hot pipes, resistors, etc., and are to be protected against mechanical damage.

2.12.9.4 Cables are not to be installed across expansion joints in any structure. Where this is unavoidable, a loop of cable having a length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

2.12.9.5 Cables having insulating materials with different maximum rated conductor temperatures are not to be bunched together. Where this is unavoidable, the cables are to be so installed that no cable reaches a temperature higher than that permitted for the cable with the lowest temperature rating in the bunch.

2.12.9.6 Cables having a protective covering or sheathing which may damage the covering or sheathing of other cables are not to be bunched together.

2.12.9.7 Where the main bus-bar is subdivided into two or more independent sections in accordance with the requirements of 2.1.1.1(5) of this Chapter, cables from different main generators to main switchboards are to follow at least two routes which are to be as far apart as practicable, for example from port and starboard or from different deck platforms.

2.12.9.8 Where a duplicate supply is required for essential electrical equipment, such as the two cables for the supply of the control box of navigation lights, the two cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.9 In the case of duplicated essential services, or systems which could operate as each other's stand-by for an essential function (such as duplicated power equipment of steering gears), the supply and any associated control cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.10 In passenger ships, distribution systems are to be so arranged that fire in any main vertical zone as defined in PART SIX of the CCS Rules for Classification of Sea-going Steel Ships will not interfere with supply to services essential for safety in any other such zone. The requirement is considered satisfied if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

2.12.9.11 Cables serving essential services or emergency power equipment, emergency lighting and internal communications or signals used in an emergency are to be as far as practicable routed clear of galleys, laundries, machinery spaces and their casings and other high fire risk areas, except for supplying equipment in these spaces.

Where possible, these cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

2.12.9.12 Main cable runs and cables for the supply and control of essential services are to be kept away from the machinery and machinery parts① having an increased fire risk unless:

(1) the cables serve such installations;

(2) the cables are separated by a steel bulkhead or deck from such installations;

(3) the cables are of a fire-resisting type.

2.12.9.13 Where trunk cables are laid in concealed manner, the panelling in way of which is to be arranged for easy removal.

2.12.9.14 Cables are not to be directly embedded in the thermal or sound insulation made of combustible material. Where cables are separated by non-combustible covering, they may be laid in the insulation, but the load carried is to be reduced accordingly.

2.12.9.15 The arrangement and run of fire resistant cables are to be in compliance with the following:

(1) Cables are to be so arranged that the loss of these services due to a localized fire at any one area or zone specified in 2.12.3.4 of this Section is minimized.

(2) Cables are to be run as straight as is practicable.

2.12.9.16 Cables of intrinsically safe circuits are to be laid apart from those for non-intrinsically safe circuits, e.g. neither bundled together or placed in the same casing or pipe, nor fixed by common clamps. The outer sheath of the cable is to be coloured blue or alternatively black with clearly visible blue stripes.

Intrinsically safe circuits of "ia" and "ib" class are not to be run in the same cable and to have their own separate cables.

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① Machinery, machinery parts or equipment containing combustibles are considered to have an increased fire risk.

**2.12.10 Means to limit the propagation of fire along bunched cables**

2.12.10.1 Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards (see 2.12.3.3) are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables①, as required in 2.12.10.2 to 2.12.10.4.

2.12.10.2 Fire dampers are to be provided (see Figure 2.12.10.2).

(1) Cables laid vertically in enclosed or semi-enclosed spaces are to be provided with fire dampers in the following locations:

① at every second deck or approximately 6 m, except cables installed within the fully-closed trunking;

② at cable entrances of main switchboard and emergency switchboard;

③ at cable entrances of engine control room;

④ at cable entrances of centralized control panels for propulsion machinery and essential auxiliary machinery;

⑤ at each end of the fully-closed cable duct.

(2) Cables laid horizontally in closed or semi-enclosed spaces are to be provided with fire dampers in the same locations required in (1), but the maximum spacing of fire dampers may be increased to 14 m.

(3) In the passageways having a height lower than the neck of a standing person within cargo holds and cargo areas, fire dampers can only be fitted on the boundaries of compartments.

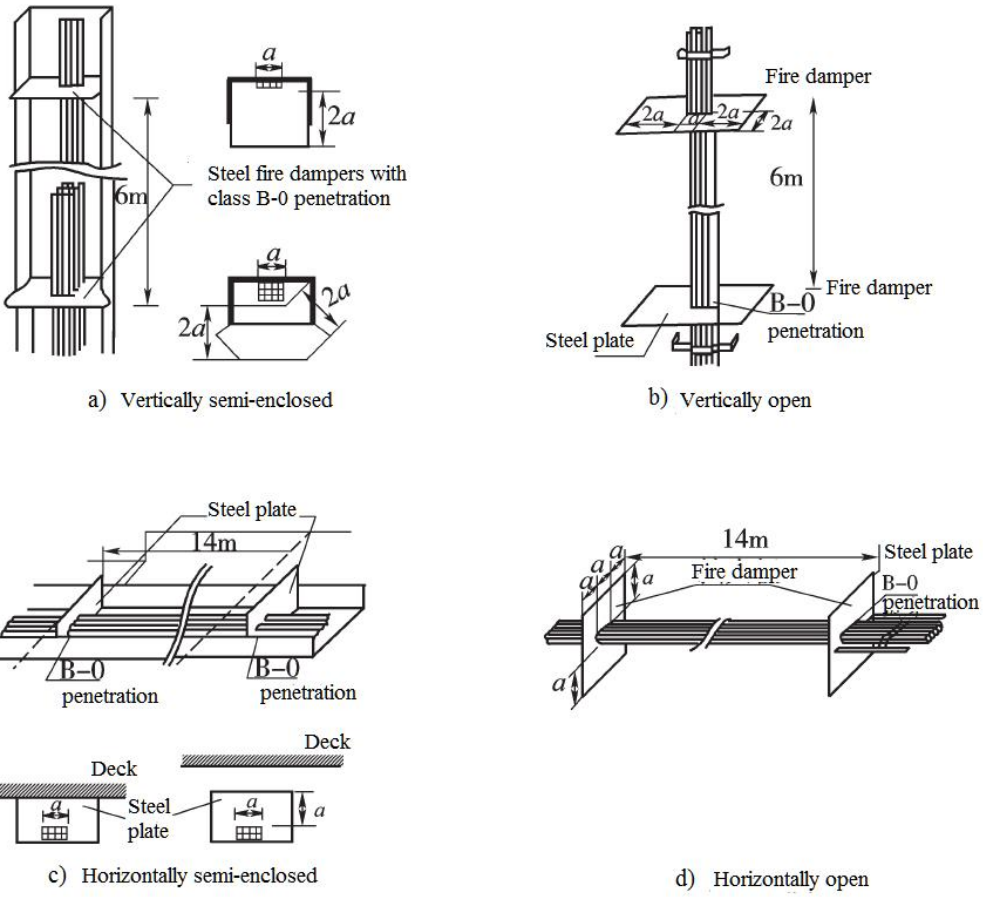
2.12.10.3 The fire dampers are to be designed to meet the following requirements:

(1) The fire resistance of cables passing through fire stops must meet the requirements for class B-0 divisions.

(2) Fire dampers are to be made of steel plate with the thickness of at least 3 mm.

(3) Where cables are laid vertically in the non-fully-closed trunking, the fire damper is to cover the sectional area of the trunking.

(4) Where cables are laid open, the fire damper is to extend around to twice the maximum laying size of cables, but not to penetrate ceilings, decks, bulkheads or the rigid sidewall of trunking.




a) Vertically semi-enclosed

b) Vertically open

c) Horizontally semi-enclosed

d) Horizontally open

**Figure 2.12.10.2 Locations of Fire Dampers**

① The bunched cables mentioned here are 5 or more cables from machinery spaces and high fire hazard spaces and more than 10 cables from other spaces are laid close together in the cable trunking.

2.12.10.4 Instead of the fire dampers required above, installed cable bunches may be provided with flameproof coating:
(1) over a length of 1 m in every 14 m for horizontal cable runs (see Figure 2.12.10.4a);
(2) over the entire length of vertical cable runs (see Figure 2.12.10.4b).

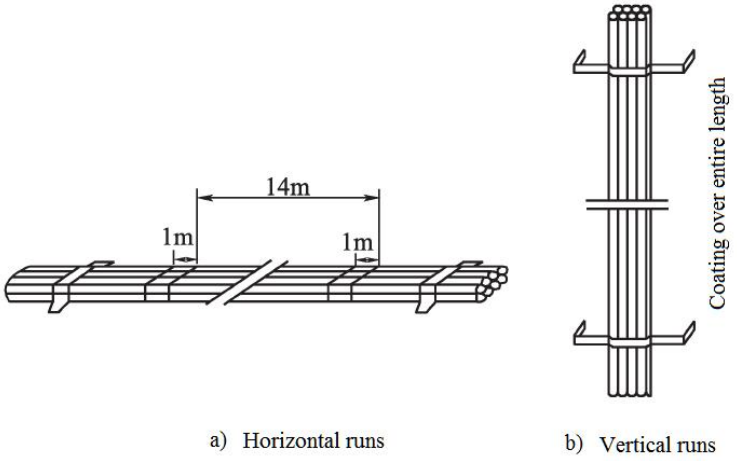



**Figure 2.12.10.4 Location of Flameproof Coating**

### 2.12.11 Mechanical protection of cables

2.12.11.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casings or enclosed in steel conduits, unless the protective sheathing of cables is sufficient to withstand the possible damage.
2.12.11.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured.
2.12.11.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.
2.12.11.4 Where cables are placed underneath the floor plates in machinery spaces, reliable precautions are to be taken to prevent such cables from being soaked in oil or water, or being exposed to mechanical damage.

### 2.12.12 Radius of bend

2.12.12.1 The minimum internal radius of bend of installed cables is to be generally in accordance with the manufacturer's recommendations, and is not to be less than the provisions of Table 2.12.12.1(1) and Table 2.12.12.1(2).

**Minimum Internal Radius of Bends in Cables Rated up to 1.8/3kV Table 2.12.12.1(1)**

| Cable construction | | Overall diameter of cable *D* (mm) | Minimum internal radius of bend *F* |
|---|---|---|---|
| Insulation | Outer covering | | |
| Thermoset material (circular copper conductor) | Not armoured or not braided | ≤ 25 | 4*D* |
| | | > 25 | 6*D* |
| | Metal sheathed, braided or armoured | Any | 6*D* |
| | Metal thread armoured, metal strip armoured | Any | 6*D* |
| | Synthetic polyester/metal sheathed slice or combined sheathed | Any | 8*D* |
| Thermoset material (circular copper conductor) | Any | Any | 8*D* |

**Minimum Internal Radius of Bends in Cables Rated at 3.6/6.0(7.2) kV and above**
**Table 2.12.12.1(2)**

| Cable construction | Overall diameter of cable *D* (mm) | Minimum internal radius of bend *F* |
|---|---|---|
| Single core cable | Any | 12*D* |

| | | |
|---|---|---|
| 3-core cable | Any | 9*D* |

**2.12.13 Securing of cables**

2.12.13.1 Cables are to be effectively supported and secured with the exception of cables for portable appliances and of those installed in pipes, conduits, trunking or special casings.

2.12.13.2 Clips or straps are to be robust and are to have a sufficient surface area and a certain shape so that the cables may remain tight without their covering or sheathing being damaged.

2.12.13.3 Clips, supports and accessories are to be made of corrosion-resistant material or suitably corrosion inhibited before erection.

2.12.13.4 The distance between supports is to be suitably chosen according to the type of cables and the possible vibration, and is generally to be in accordance with Table 2.12.13.4.

**External Diameter of Cable and Distance between Supports Table 2.12.13.4**

| External diameter of cable (mm) | | Distance between supports (mm) | |
|---|---|---|---|
| Exceeding | Not exceeding | Non-armoured cables | Armoured cables |
| – | 8 | 200 | 250 |
| 8 | 13 | 250 | 300 |
| 13 | 20 | 300 | 350 |
| 20 | 30 | 350 | 400 |
| 30 | – | 400 | 450 |

2.12.13.5 When cables are fixed by means of non-metallic clips or straps, and are not laid on top of horizontal cable trays or supports, suitable metal cable clips or straps are to be added at regular distances not greater than 1 m in order that in the event of a fire, cables are prevented from falling and causing an injury to personnel or an obstruction to any escape route.

**2.12.14 Penetration of bulkheads and decks by cables**

2.12.14.1 Penetration of watertight bulkheads or decks may be carried out with either individual watertight glands or with packed watertight boxes carrying several cables, provided that the watertight integrity of the bulkheads or decks is to be maintained.

2.12.14.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material.

If the steel is 6 mm or more in thickness, adequately rounded edges may be accepted as the equivalent of bushing.

2.12.14.3 Penetration of bulkheads and decks requiring a certain fire integrity is to be so effected as to ensure that the required fire integrity is not impaired.

2.12.14.4 Cables passing through decks are to be protected by deck tubes or ducts having a suitable height.

2.12.14.5 Materials used for glands and bushings are to be such that there is no risk of corrosion to cables or hull structures.

2.12.14.6 Where rectangular holes are cut in bulkheads or structural steel, the corners of the holes are to be radiused.

2.12.14.7 Where a cable transit seal system is used, a register is to be developed according to Appendix 3, Chapter 4, PART ONE of the CCS Rules for Classification of Sea-going Steel Ships.

**2.12.15 Installation of cables in pipes, conduits or trunking**

2.12.15.1 When cables are installed in metal pipes, conduits or trunking, the following requirements are to be complied with:

(1) The internal surfaces of the pipes, conduits or trunking are to be smooth and protected against corrosion.

(2) Provision is to be made at the ends of pipes, conduits or trunking so as to protect the sheathing or covering of cables from being damaged.

(3) The internal sectional area and radius of bend of pipes or conduits are to be such as to permit easy drawing in and out the cables contained therein; the internal radius of bend of pipes or conduits is not to be less than that allowed for cables, provided that for pipes equal to or above 63 mm in external diameter, the internal radius of bend is not less than twice the external diameter of the pipe.

(4) The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-sectional area of the pipe) is not to exceed 0.4.

(5) Pipes, conduits or trunking are to be effectively earthed.

(6) Pipes, conduits or trunking are to be so arranged that water will not accumulate inside them (consideration being given to possible condensation).
(7) If necessary, ventilation openings are to be provided, preferably at the highest and lowest points, so as to permit air circulation and to prevent possible accumulation of water at any part of the pipes, conduits or trunking. This may be done only if the fire risk will not be increased thereby.
(8) Expansion joints are to be provided where necessary for long pipe run.
2.12.15.2 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.
2.12.15.3 Cables used for cold cathode luminous discharge lamps are not to be installed in metal conduits unless protected by metal screen.

**2.12.16 Installation of cables in refrigerated spaces**
2.12.16.1 Cables not serving refrigerated spaces are not to pass through such spaces. Cables installed in refrigerated spaces are to have an impervious sheath and are to be protected against mechanical damage. If an armoured cable is used, the armour is to be protected against corrosion by a further moisture-resisting covering (unless it has been galvanized).
2.12.16.2 Cables are to be run in the open in refrigerated spaces.
2.12.16.3 Metal supports used for securing the cables are to be galvanized or otherwise protected against corrosion.

**2.12.17 Relief of tension**
2.12.17.1 Cables are to be so installed that the tension stress applied to them either by their own weight or for any other reason is minimized. This is particularly important for cables of small cross-sections and for cables laid vertically or in vertical pipes.

**2.12.18 Electrodynamic forces**
2.12.18.1 In order to guard against the effects of electrodynamic forces in the event of short-circuit, single-core cables are to be firmly fixed and the strength of supports is to be sufficient to withstand the electrodynamic forces corresponding to the prospective short-circuit currents.

**2.12.19 Installation of single-core cables for alternating current**
2.12.19.1 For AC power systems, two-core or multi-core cables are to be used as far as practicable. Where it is necessary to use single-core cables for circuits rated in excess of 20 A, the following requirements are to be complied with:
(1) Cables are to be either non-armoured or armoured and covered with non-magnetic material.
(2) Cables belonging to the same circuit are to be contained in the same pipe, conduit or trunking. Cable clips are to include cables of all phases of a circuit, unless the clips are of non-magnetic material.
(3) In the installation of two, three or four single-core cables forming respectively single-phase, three-phase, or three-phase four-wire circuits, the cables are to be as far as possible in contact with one another. In any event, the distance between adjacent cables is not to be greater than one cable diameter.
(4) When it is necessary to install single-core cables of current rating greater than 250 A near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the single-core cables belonging to different phases are installed in trefoil formation.
(5) Magnetic material is not to be placed between single-core cables of a group for the same circuit. Where cables pass through steel plates, all conductors of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless single-core cables belonging to different phases are installed in trefoil formation.
(6) In order to equalize to some degree the impedance of three-phase circuits of considerable length consisting of single-core cables having a cross sectional area of 185 $mm^2$ or over, the phases are to be transposed at regular intervals of not exceeding 15 m. Alternatively, the three single-core cables of different phases may be installed in a trefoil formation. The above precautions are, however, not necessary when the length of the run is less than 30 m.
(7) In circuits with several single-core cables in parallel for each phase, all cables are to follow the same route and have the same cross-sectional area.
In addition, cables belonging to the same phase are, as far as practicable, to be alternated with those of other phases so that an unequal division of current is avoided. For instance, in the case of six cables for each phase, the correct dispositions are as shown in Table 2.12.19.1.

**Disposition of Cables** **Table 2.12.19.1**

| Cables in parallel for each phase | 1-layer disposition | 2-layer disposition |
|---|---|---|
| 2 | ABC CBA | ABC<br>CBA |
| 3 | | ABCA<br>BCABC |
| 4 | | ABCABC<br>CBACBA |
| 5 | | ABCABCA<br>BCABCABC |
| 6 | | ABCABCABC<br>CBACBACBA |

**2.12.20 Installation of cables with respect to prevention of electromagnetic interference**

2.12.20.1 In order to minimize the effects of unwanted electromagnetic interference, cables are to be installed in accordance with the relevant standards① accepted by CCS.

**2.12.21 Earthing of metal protective coverings of cables**

2.12.21.1 The earthing of metal protective coverings (braid or armour) of cables is to be in accordance with the relevant requirements of Section 3, Chapter 1 of this PART.

**2.12.22 Cable ends**

2.12.22.1 The ends of all conductors of a cross-sectional area greater than 4 $mm^2$ are to be fitted with soldered sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

2.12.22.2 The temperature of cable sockets and terminals is, in general, not to exceed the maximum operating temperature of insulated cables.

2.12.22.3 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and dynamic effects of short-circuit currents.

**2.12.23 Joints and tappings**

2.12.23.1 Cable runs are normally not to include joints. If a joint is necessary in the case of repair or sectional construction of the ship, the joint is to be such that the electrical continuity, insulation, mechanical strength and protection, earthing and fire-resisting or flame-retardant characteristics are not inferior to those required for the cables.

2.12.23.2 Tappings are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or bus-bars of dimensions appropriate to the current rating.

2.12.23.3 Joints and tappings are to be clearly marked.

**2.12.24 Connection boxes**

2.12.24.1 Connection boxes are to be made of flame-retardant material. Mountings of live parts are to be robust, durable, flame-retardant and moisture-resistant, having permanently insulation resistance with high dielectric strength.

2.12.24.2 Live parts within the box are to be suitably spaced or provided with shielding by flame-retardant insulating material so that a short-circuit will not occur between conductors of different polarity or between conductors and earthed metal.

2.12.24.3 Each connection box is to be provided with a nameplate indicating its purpose or a durable no. mark corresponding to the wiring diagram. Where the connection boxes are installed in a concealed manner, the panelling in way of the boxes is to be arranged for easy removal.

**2.12.25 Cable trays/protective casings made of plastic materials**

2.12.25.1 Cable trays/protective casings② made of plastic③ materials are to be type tested in accordance with Appendix 2, PART FOUR of the CCS Rules for Classification of Sea-going Steel Ships.

2.12.25.2 Cable trays/protective casings made of plastic materials are to be supplemented by metallic

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① Refer to IEC Publication 60533: Electrical and Electronic Installations in Ships – Electromagnetic Compatibility, or the relevant requirements in relevant standards.

② "Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

③ "Plastic" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.

fixing or straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.
2.12.25.3 The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer's recommendation nor in excess of spacing at the SWL test. In general the spacing is not to exceed 2 m. The selection and spacing of cable tray/protective casing supports are to take the following into account:
(1) cable trays/protective casings' dimensions;
(2) mechanical and physical properties of their material;
(3) mass of cable trays/protective casings;
(4) loads due to weight of cables, external forces, thrust forces and vibrations;
(5) maximum accelerations to which the system may be subjected;
(6) combination of loads.
2.12.25.4 The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

# Section 13 LIGHTNING PROTECTION

### 2.13.1 Protection against primary structural damage

2.13.1.1 A protective system need not be fitted to a ship of metallic construction where a low resistance path to earth will be inherently provided by masts, structural members and the hull.
2.13.1.2 A protective system is to be fitted to any ship having a substantial number of non-metallic structural members.
2.13.1.3 The protective system is to be comprised of air terminal, down conductor and earth termination.
2.13.1.4 Metallic masts and metallic structural members may form part or all of any protective system.
2.13.1.5 The metal rigging, such as stays, shrouds, etc., are to be bonded to the protective system.
2.13.1.6 Joints in down conductors are to be accessible and be located or protected so as to minimize accidental damage. They are to be made by means of copper rivets or clamps. Clamps may be of copper or of copper alloy and are to preferably be of the serrated contact type and effectively locked. No connection is to be dependent on a soldered joint.
2.13.1.7 The resistance between air terminals and earth terminations is not to exceed 0.02 Ω.
2.13.1.8 Suitable means are to be provided to enable ships when in dry dock, or on a slipway, to have their protective systems or metal hull connected to an efficient earth on shore. Connecting cables to the shore earth is to be external to the earth throughout their length.
2.13.1.9 Air terminals of the protective system are to comply with the following requirements:
(1) An air terminal is to be fitted to each non-metallic mast.
(2) Air terminals are to be made of copper or copper alloy conducting bar of not less than 12 mm diameter, and are to project at least 300 mm beyond the top of the mast. Other materials may be used, for example stainless steel or aluminium alloys, or steel bar effectively protected against corrosion, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(3) Vent outlets for flammable gases located at or near the top of masts on tankers are to be protected by air terminals which extend at least 2 m above the vent outlet. A steel mast may serve as the air terminal if it extends 2 m above the outlet.
2.13.1.10 Down conductors of the protective system are to comply with the following requirements:
(1) Down conductors are to be made of copper, or copper alloy tape or cable. Cable is preferred as both the insulation and the circuit shape inhibit surface discharge. Other materials may be used, for example stainless steel or aluminium alloys, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(2) Down conductors of copper are to have a minimum cross-section of 70 $mm^2$, be firmly secured to the structure and be run as straight as possible between the air terminal and the earth termination. Bends, where necessary, are to have a minimum radius of at least 10 times the equivalent diameter of the conductor.
2.13.1.11 The ends of down conductors are to be reliably bonded to the earth terminations of the metallic construction of the ship nearby. Where necessary, measures are to be taken for preventing electrochemical corrosion.

### 2.13.2 Protection against secondary damage

2.13.2.1 On all ships, equipment is to be so installed as to minimize the effect of secondary damage

caused by lightning to the electrical system.
2.13.2.2 Metallic enclosures are to be reliably earthed. Particular attention is to be paid to navigation lights and other equipment at the top of masts and on other elevated structures.
2.13.2.3 Cable screens or armour, though normally earthed for signal interference suppression, are not to provide the sole lightning path to earth for equipment. Separate earthing, as required in 2.13.2.2, is to be provided.
2.13.2.4 The formation of cable loops, or metallic loops such as pipework, in proximity to down conductors of the protective system required in 2.13.1.2 is to be avoided. Cables in close proximity to down conductors are to be installed in metal pipes.
2.13.2.5 Cables along decks are to be installed close to the deck and advantage is to be taken of the screening effect of earthed metallic structures near to or above the cable runs, for examples handrails, pipes, etc.
2.13.2.6 Means are to be provided for the discharging to earth of any lightning energy that may be induced in for example radio and navigational equipment antennas. Consideration is to be given to installing devices such as spark gaps or surge diverters to provide protection from voltage transients.

# Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS

### 2.14.1 General requirements

2.14.1.1 This Section applies to AC three-phase systems with nominal voltage (voltage between phases) exceeding 1 kV. If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.
2.14.1.2 The nominal system voltage is not to exceed 15 kV. Where necessary for special application, higher voltages may be accepted.
2.14.1.3 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

### 2.14.2 System design

2.14.2.1 The distribution of high-voltage electrical installations is to comply with the following:
(1) It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.
Services which are duplicated are to be divided between the sections.
(2) For earthed neutral systems in case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.
It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.
(3) Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.
(4) All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.
(5) In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each separate section of the main switchboard.
2.14.2.2 The degrees of protection provided by enclosures for the high-voltage electrical equipment is to be appropriate to the location of installation, as a minimum in compliance with the requirements of Table 1.3.2.2 of this PART and in addition the following:
(1) The degree of protection by enclosures for rotating electrical machines is to be at least IP23. The degree of protection of terminals is to be at least IP44. For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.
(2) The degree of protection by enclosures for transformers is to be at least IP23. For transformers installed

in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
For transformers not contained in enclosures, 2.14.7.1 of this Section is to be complied with.
(3) The degree of protection of metal enclosed switchgear, control gear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
2.14.2.3 The air clearances and creepage distances are to comply with the following:
(1) In general, for non-type-tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are not to be less than those specified in Table 2.14.2.3.
Where intermediate values of nominal voltages are accepted, the next higher air clearance is to be observed. In the case of smaller clearances, appropriate voltage impulse test is to be applied.

**Minimum Air Clearances** **Table 2.14.2.3**

| Nominal voltage (kV) | Minimum air clearance (mm) |
|---|---|
| 3 (3.3) | 55 |
| 6 (6.6) | 90 |
| 10 (11) | 120 |
| 15 | 160 |

(2) Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with IEC Publication 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.
2.14.2.4 For protection of the high-voltage electrical system, the following special requirements are to be complied with:
(1) Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and automatically de-excite the generator.
In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.
(2) Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems (a system is defined effectively earthed when the earthing factor① is lower than 0.8), provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems (a system is defined non-effectively earthed when the earthing factor is higher than 0.8), where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.
(3) Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.
(4) Voltage transformers are to be provided with overload and short circuit protection on the secondary side.
(5) Fuses are not to be used for overload protection.
(6) Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:
① direct earthing of the lower voltage system;
② appropriate neutral voltage limiters;
③ earthed screen between the primary and secondary windings of transformers.

### 2.14.3 Rotating machinery

2.14.3.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.
2.14.3.2 Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.
If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.
2.14.3.3 In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with acceptable standard(s)② is to be carried out on the individual coils in order to

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① Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/\sqrt{3}$ and 1.

② Refer to IEC Publication 60034-15 Rotating electrical machines – Part 15: Impulse voltage withstand levels of rotating

demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

### 2.14.4 Power transformers

2.14.4.1 Dry type transformers are to comply with acceptable standard(s)[①], and liquid cooled transformers are also to comply with acceptable standard(s)[②].

2.14.4.2 Oil immersed transformers are to be provided with the following alarms and protections:

(1) liquid level (Low) – alarm;
(2) liquid temperature (High) – alarm;
(3) liquid level (Low) – trip or load reduction;
(4) liquid temperature (High) – trip or load reduction;
(5) gas pressure relay (High) – trip.

### 2.14.5 Cables

2.14.5.1 Cables are to be constructed in accordance with acceptable standards[③].

### 2.14.6 Switchgear and control gear assemblies

2.14.6.1 Switchgear and control gear assemblies are to be constructed according to acceptable standards[④].

2.14.6.2 Switchgear and control gear assemblies are to be constructed in accordance with the following requirements:

(1) Switchgear is to be of metal-enclosed type or of the insulation-enclosed type in accordance with acceptable standard(s)[⑤].

(2) Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

(3) The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered. Shutters are to be clearly marked for incoming and outgoing circuits. This may be achieved with the use of labels or colours.

(4) For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

(5) Switchgear and controlgear assemblies are to be internal arc classified (IAC). Where switchgear and controlgear assemblies are accessible by authorized personnel only, Accessibility Type A is sufficient (refer to IEC Publication 62271-200; Annex AA; AA 2.2). Accessibility Type B is required if accessible by non-authorized personnel. Installation and location of the switchgear and controlgear assemblies are to correspond with their internal arc classification and classified sides (F, L and R).

2.14.6.3 Requirements for auxiliary systems

(1) If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two consecutive operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

(2) When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or set of essential services. Where necessary, one source of supply is to be from the emergency source of electrical power for the start-up from dead ship condition.

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AC machines with form-wound stator coils, or other equivalent standards.

① Refer to IEC Publication 60076-11 Dry-type power transformers, or other equivalent standards.

② Refer to the applicable Parts of the IEC Publication 60076 Series, or other equivalent standards.

③ Refer to IEC Publication 60092-353 Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV and IEC Publication 60092-354 Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7.2 kV) up to 30 kV (Um = 36 kV).

④ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, or other equivalent standards.

⑤ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, and compliance with IEC Publication 62271-201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

2.14.6.4 A power-frequency voltage test is to be carried out on any switchgear and control gear assemblies. The test procedure and voltages are to be according to acceptable standard(s)[①].

**2.14.7 Installation**

2.14.7.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regards the high-voltage electrical equipment installed outside a.m. spaces, the similar marking is to be provided.

An adequate, unobstructed working space is to be left in the vicinity of high voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling/deckhead above is to meet the requirements of the internal arc classification[②].

2.14.7.2 Run of high-voltage cables is to comply with the following:

(1) In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

(2) High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same duct or pipe, or, in the same box.

Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in 2.14.2.3(1) of this Section. However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV and less.

(3) High-voltage cables, in general, are to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic casings effectively bonded to earth.

(4) Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials. High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc.).

(5) High-voltage cables are to be readily identifiable by suitable marking.

(6) Before a new high voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test is then repeated. The voltage withstand test is to be carried out in accordance with the following methods:

① For cables with rated voltage above 1.8/3 kV ($U_m$[③]=3.6 kV) an a.c. voltage withstand test may be carried out upon advice from high voltage cable manufacturer. One of the following test methods may be used: test for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen/sheath, or test for 24 h with the normal operating voltage of the system; alternatively, a d.c. test voltage equal to 4 $U_0$ may be applied for 15 min.

② For cables with rated voltage up to 1.8/3 kV ($U_m$=3.6 kV) a d.c. voltage equal to 4 $U_0$ is to be applied for 15 min.

# Section 15 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY

Electrical propulsion machinery is to comply with the applicable requirements of this PART and the

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① Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV – Part 7: Routine test, or other equivalent standards.

② Refer to 6.2.5 of IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

③ *U*m is the maximum value of the "highest system voltage" for which the equipment may be used. Highest system voltage is the highest value of voltage which occurs under normal operating conditions at any time and at any point on the system. It excludes voltage transients, such as those due to system switching, and temporary voltage variations.

requirements of Chapter 15, PART EIGHT of the CCS Rules for Classification of Sea-going Steel Ships.

# Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS

**2.16.1 General requirements**

2.16.1.1 Electrical installations on tankers carrying crude oil and oil products are to comply with the provisions of this Section and other provisions of this PART as appropriate.

2.16.1.2 The classification of typical hazardous areas of oil tankers is carried out in accordance with zone 0, zone 1 and zone 2 based on the provisions of IEC Publication 60092-502 in this Section. For areas or spaces not mentioned in this Section, the classification of hazardous areas may be carried out in accordance with the principles given in IEC Publication 60079-10-1.

2.16.1.3 Electrical equipment and cables are, in principle, not to be installed in any hazardous areas. If it is impracticable to avoid doing so, the relevant provisions of this Section are to be complied with.

**2.16.2 Distribution systems**

2.16.2.1 The following distribution systems may be used:

(1) DC, two-wire, insulated;

(2) AC, single-phase, two-wire, insulated;

(3) AC, three-phase, three-wire, insulated.

2.16.2.2 No direct electrical connection is allowed between power networks operating at different voltages.

2.16.2.3 All circuits of generation, supply and distribution systems are not to be earthed, and hull return system is not permitted with the following exceptions:

(1) intrinsically safe circuits;

(2) power supplied control circuits and instrumentation circuits where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions;

(3) limited and locally earthed systems, provided that any possible resulting current does not flow directly through any of the hazardous spaces;

AC distribution systems with 1,000 V (root mean square) and over between phases, provided that any possible resulting current does not flow directly through any of the hazardous spaces.

**2.16.3 Cables and their installation**

2.16.3.1 All cables, other than those of intrinsically safe circuits, installed in zone 0 and zone 1, are to be provided with an impervious sheath in combination with braiding or other metallic covering.

2.16.3.2 Cables of intrinsically safe circuits are to have a metallic shielding with at least an impervious sheath.

2.16.3.3 Where cables are subject to lengthy immersion in the cargo, the construction of the cables is to be such as to withstand the substances to which they can be exposed, or the cables are to be enclosed in casings (such as metallic pipes) capable of withstanding such substances.

2.16.3.4 Where corrosion may be expected, an impervious sheath is to be applied over the metal braid or armour of the cable.

2.16.3.5 Where cables pass through gastight bulkheads or decks separating hazardous areas from non-hazardous areas, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

2.16.3.6 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be so installed as to avoid strain or chafing and due allowance is to be made for expansion or working of the structure. Where ring-type expansion bends are fitted, they are to be accessible for maintenance.

2.16.3.7 Cables installed in pump rooms are to be suitably protected against mechanical damage.

2.16.3.8 Flexible cables or wires for portable electrical appliances are not to pass through hazardous areas or spaces, with the exception of flexible cables or wires of intrinsically safe type.

**2.16.4 Electrical equipment in hazardous areas**

2.16.4.1 For electrical equipment installed in hazardous areas, the appropriate certified explosion-proof equipment is to be selected in accordance with the category of hazardous areas, and the explosion group and temperature class are not to be lower than II A T3.

2.16.4.2 The following equipment is allowed to be installed in zone 0:

(1) certified intrinsically-safe apparatus of category “ia”;
(2) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category “ia”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC Publication 60079-14;
(3) submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.

2.16.4.3 The following equipment is allowed to be installed in zone 1:
(1) electrical equipment specified in 2.16.4.2 of this Section;
(2) certified intrinsically-safe apparatus of category “ib”;
(3) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category “ib”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC Publication 60079-14;
(4) certified flameproof (type “d”);
(5) certified pressurized (type “p”);
(6) certified increased safety (type “e”);
(7) certified encapsulated (type “m”);
(8) certified sand filled (type “q”);
(9) certified specially (type “s”)[①];
(10) anodes or electrodes of an impressed current cathodic protection system, or transducers such as those for depth-sounding or log systems, provided that such fittings are housed within a gastight enclosure, and are not located adjacent to a cargo tank bulkhead;
(11) through runs of cable.

2.16.4.4 The following equipment is allowed to be installed in zone 2:
(1) electrical equipment specified in 2.16.4.3 of this Section;
(2) non-sparking electrical equipment “n”;
(3) the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation.

2.16.4.5 Transmitting aerials and any associated riggings are to be sited well clear of gas and vapour outlets.

2.16.4.6 For the electrical equipment permitted in hazardous areas or spaces, all switches and protective devices are to be capable of interrupting all poles or phases and are to be located in a non- hazardous area or space. Such equipment, switches and protective devices are to be clearly and durably labelled for identification purposes.

### 2.16.5 Earth connection and static electricity protection

2.16.5.1 The metal casings of all electrical equipment in any hazardous areas or spaces, regardless of the working voltage, are to be reliably earthed.

2.16.5.2 Cargo tanks, process plants and piping systems are to be earthed in accordance with 1.3.4.12 of this PART for the control of static electricity.

2.16.5.3 All rigging is to be effectively bonded to ship’s hull.

### 2.16.6 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃

2.16.6.1 Zone 0 is to include the following areas or spaces:
(1) cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks;
(2) interior spaces containing the pipes and equipment containing cargo oil.

2.16.6.2 Zone 1 is to include the following areas or spaces:
(1) cofferdams and ballast tanks adjoining cargo tanks;
(2) cargo pump rooms and the mechanical ventilation is to comply with the following requirements:
① audible and visual alarms are to be given at a manned location in case of failure of the mechanical ventilation in the cargo pump room;
② actions are to be taken to restore ventilation immediately after failure of the mechanical ventilation;
③ where the mechanical ventilation can not be restored for an extended period, the remaining electrical equipment other than those mentioned below is to be capable of being disconnected outside of hazardous areas and provided with means against unauthorized re-connections:

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① Where explosion-proof types (flameproof, increased safety, intrinsically-safe, pressurized, oil filled, sand filled, encapsulated and non-sparking) not included in the special standards are used for electrical equipment, they may be treated as electrical equipment certified specially (type “s”).

(a) intrinsically safe equipment;
(b) flameproof lighting;
(c) general emergency alarm sounder of flameproof type, without internal sparking contacts;

④ where the mechanical ventilation has been stopped for an extended period or it is initially used, the cargo pump room is to be purged for at least five air changes before connecting the electrical equipment (except the intrinsically safe equipment, flameproof lighting and general emergency alarm sounder of flameproof type);

(3) enclosed or semi-enclosed spaces immediately above cargo tanks (e.g. 'tween-deck spaces) or having bulkheads above and in line with cargo tank bulkheads;

(4) spaces other than cofferdams adjoining to and below the top of a cargo oil tank (e.g. trunks, passageways and general cargo holds), and double bottom and pipe tunnels below cargo tanks;

(5) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet①, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(6) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet;

(7) areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;

(8) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck;

(9) areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(10) compartments for cargo hoses;

(11) enclosed or semi-enclosed spaces in which pipes containing cargoes are located;

(12) fore peak tank and vent pipe openings as defined in 3.4.14.1, Chapter 3, PART SIX of the CCS Rules for Classification of Sea-going Steel Ships.

2.16.6.3 Zone 2 is to include the following areas or spaces:

(1) areas of 1.5 m surrounding the open spaces or semi-enclosed spaces in zone 1 as specified in 2.16.6.2, if not otherwise specified in this standard;

(2) spaces 4 m beyond the area defined in 2.16.6.2(6);

(3) areas within 2 m beyond areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) the spaces forming an air-lock leading to zone 1;

(5) areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above the deck;

(6) areas on open deck over all oil cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1;

(7) spaces forward of the open deck areas to which reference is made in 2.16.6.2(8) and 2.16.6.3(6) of this Section, below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:

① the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m from the foremost cargo tank and at least 10 m measured horizontally from any cargo tank outlet or gas or vapour outlet; and

② the spaces are mechanically ventilated.

2.16.6.4 The hazards in some hazardous areas or spaces, e.g. those having direct openings into hazardous areas or spaces, may be reduced or these zones or spaces may be regarded as non-hazardous areas or spaces, provided that the arrangements of ventilation, pressurization, doors at openings, and other safety

① Such areas are sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

precautions are in compliance with relevant acceptable standards①.

**2.16.7 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and not heated or heated to a temperature more than 15℃ below their flash point**

2.16.7.1 The interiors of cargo tanks, slop tanks, any pipework of pressure/vacuum relief valve or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or handling flammable gas or vapour belong to zone 2.

**2.16.8 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and heated to a temperature above their flash point or heated to a temperature within 15℃ of their flash point**

2.16.8.1 Such tankers are to comply with the requirements for oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃, as specified in 2.16.6 of this Section.

# Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

**2.17.1 General requirements**

2.17.1.1 This Section applies to the electrical installations of ships with spaces for carrying vehicles with fuel in their tanks for their own propulsion.

2.17.1.2 The certified explosion-proof equipment required by this Section is to comply with the provisions of 1.3.3 of this PART, and the explosion group and temperature class are not to be lower than II A, T3.

**2.17.2 Carriage of vehicles in special category spaces above the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with not less than 10 air changes per hour) of passenger ships and cargo ships**

2.17.2.1 The electrical equipment fitted within a height of 450 mm above the vehicle deck or any platform on which vehicles are carried and within the exhaust ventilation trunking for the spaces is to be of certified safe type.

2.17.2.2 In spaces other than those specified in 2.17.2.1, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type.

**2.17.3 Carriage of vehicles in special category spaces below the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with less than 10 air changes per hour) of passenger ships and cargo ships**

2.17.3.1 The electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.

**2.17.4 Carriage of vehicles in cargo spaces other than vehicle, special category or ro-ro spaces**

2.17.4.1 On all ships, when vehicles with fuel in their tanks for their own propulsion are carried in cargo spaces other than vehicle, special category or ro-ro spaces, the requirements of SOLAS regulation II-2/20.2.1.2 are to be complied with.

**2.17.5 Carriage of vehicles in open ro-ro spaces, open vehicle spaces and an area on weather deck of passenger ships and cargo ships**

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART.

① See IEC Publication 60092-502: Electrical installations in ships –Part 502: Tankers – Special Features.

# Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

### 2.18.1 General requirements

2.18.1.1 The electrical installations onboard ships fitted with cargo spaces intended for carrying dangerous goods specified in 2.18.1.2 are to comply with the requirements of this Section and other applicable requirements of this PART.

2.18.1.2 Dangerous goods, for which safety measures are required with respect to the electrical equipment, are grouped into the following classes in accordance with IMO International Maritime Dangerous Goods Code (IMDG Code) and International Maritime Solid Bulk Cargoes (IMSBC) Code:

(1) Dangerous goods in packaged form

Class 1 Explosives, except goods in division 1.4, compatibility group S of IMDG Code;

Class 2.1 All flammable gases, compressed, liquefied or dissolved under pressure;

Class 2.3 All toxic gases having a subsidiary risk class 2.1;

Class 3 All flammable liquids having a flashpoint below 23℃ (closed-cup test);

Class 4.3 Liquids having a flashpoint below 23℃, which in contact with water, emit flammable gases;

Class 6.1 All toxic substances having a flashpoint below 23℃ (closed-cup test);

Class 8 All corrosive liquids having a flashpoint below 23℃ (closed-cup test);

Class 9 Miscellaneous dangerous substances emitting flammable gases.

(2) Solid dangerous goods in bulk

Class 4.1 Flammable solids;

Class 4.2 Substances liable to spontaneous combustion;

Class 4.3 Substances, which in contact with water, emit flammable gases;

Class 5.1 Oxidizing substances;

Class 9 Miscellaneous dangerous substances, that is, any other substance which experience has shown, or may show, to be of such a dangerous character that the provisions of this Section apply to it;

MHB Materials which may possess chemical hazards when transported in bulk other than materials classified as dangerous goods in the IMDG Code.

2.18.1.3 Possible hazardous areas for carrying the dangerous goods specified in this Section comprise the following:

(1) Zones and spaces, in which an explosive atmosphere① is likely to occur in normal operation, are defined as hazardous areas.

(2) Zones and spaces, in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only, are defined as extended hazardous areas.

2.18.1.4 Electrical equipment is to be installed in hazardous areas only when it is essential for the safety and operation of the ship. The explosion protection of the installed and operated electrical equipment is to be suitable for the characteristics of the dangerous goods.

### 2.18.2 Carriage of explosives class 1 in packaged form as specified in 2.18.1.2 (1) (except goods in division 1.4, compatibility group S)

2.18.2.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces, and closed or open ro-ro cargo spaces;

(2) permanently fixed containers (e.g. magazines).

2.18.2.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.2.2 are permitted in the hazardous areas specified in 2.18.2.1 of this Section.

**Permitted Electrical Equipment** **Table 2.18.2.2**

| Environment | Electrical equipment | | | |
|---|---|---|---|---|
| | Type | Explosion group | Temperature class or maximum surface temperature | Degree of protection |
| Explosive dust | General electrical equipment | | 100℃ | IP65 |
| Explosive gas | Intrinsically safe Ex “i” | IIA | T5 | |
| | Flameproof Ex “d” | IIA | | |

① An explosive atmosphere may exist due to gas and/or dust.

| | | | | |
|---|---|---|---|---|
| | Increased safety Ex “e” (only for lighting) | II | | |
| Explosive gas and dust | Intrinsically safe Ex “i” | IIA | T5 | IP65 |
| | Flameproof enclosure Ex “d” | IIA | | |
| | Increased safety Ex “e” (only for lighting) | II | | |

**2.18.3 Carriage of solid dangerous goods in bulk, including classes 4.1, 4.2, 5.1, 9 and MHB creating explosive dust atmosphere**

2.18.3.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) or (2) above, without appropriate measures to prevent flammable dust from entering.

2.18.3.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required as follows are permitted in the hazardous areas specified in 2.18.3.1 of this Section(unless otherwise specified in 2.18.5):

(1) general electrical equipment

— degree of protection IP55;

— maximum surface temperature 200℃; or

(2) certified explosion-proof electrical equipment

— degree of protection IP55;

— temperature class T3.

2.18.3.3 Where dangerous goods are to be carried which require a lower surface temperature than that given in 2.18.3.2 of this Section, the relevant requirements are to be complied with (see also 2.18.7).

2.18.3.4 Where ammonium nitrate (UN1942) and ammonium nitrate fertilizer (UN2067) of class 5.1, ammonium nitrate fertilizer (UN2071) of class 9, ammonium nitrate-based fertilizer and ammonium nitrate-based fertilizer MHB are to be carried, all electrical equipment, other than that of certified safe type, in hazardous areas are to be electrically disconnected from the power source in accordance with the requirements of 2.18.8.1.

**2.18.4 Carriage of flammable liquids having a flashpoint below 23℃ (classes 3, 6.1 and 8), flammable gas in packaged form (class 2.1), miscellaneous dangerous substances emitting flammable gases in packaged form (class 9) and substances emitting flammable gases in contact with water (solid class 4.3 and MHB generating flammable gases in contact with water)**

2.18.4.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces and closed ro-ro cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) areas on weather deck, or semi-enclosed spaces on weather deck, within 1.5 m of any exhaust ventilation outlet of a hazardous area;

(4) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) and (2) above, and without appropriate measures to prevent flammable gas from entering.

2.18.4.2 The following zones or spaces are extended hazardous areas:

(1) spaces which are separated by self-closing gastight doors (watertight doors may be regarded as gastight) from the hazardous areas as mentioned in 2.18.4.1(1) and (2), and have natural ventilation;

(2) inside the air lock (if any) adjoining the hazardous areas as mentioned in 2.18.4.1;

(3) open or semi-enclosed spaces within 1.5 m of the hazardous areas as specified in 2.18.4.1(3).

2.18.4.3 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.4.3 are permitted in the hazardous areas specified in 2.18.4.1 and 2.18.4.2 of this Section (unless otherwise specified in 2.18.5).

**Permitted Electrical Equipment** **Table 2.18.4.3**

| Type of hazardous areas | Electrical equipment | | |
|---|---|---|---|
| | Type | Explosion group | Temperature class or maximum surface temperature |
| Hazardous areas | Intrinsically safe Ex “i” | IIC | T4 |
| | Flameproof Ex “d” | IIC | |
| | Pressurized enclosure Ex “p” | II | |
| | Encapsulated Ex “m” | II | |
| Extended hazardous areas | Electrical equipment permitted in the above hazardous areas | IIC or II | T4 |
| | Non-sparking Ex “n” | II | |
| | Appliances which do not generate sparks or arcs during normal operation | | 135℃ |

2.18.4.4 If cargoes to be carried do not include hydrogen gases, hydrogen mixtures or bulk cargo which may produce hydrogen under certain conditions, the explosion group required above may be IIB.

### 2.18.5 Carriage of solid dangerous goods in bulk and MHB only

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB are to be carried, electrical equipment of certified safe type installed in hazardous areas are to be in compliance with the minimum requirements of Table 2.18.5.1.

**Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)**

**Table 2.18.5.1**

| Dangerous goods | IMO class | Dominant risk① | Protection against explosive dust atmosphere | Protection against explosive gas atmosphere | |
|---|---|---|---|---|---|
| | | | Degree of protection | Explosion group | Temperature class |
| Aluminium ferrosilicon powder UN1395 | 4.3 | $H_2$ | — | IIC | T2 |
| Aluminium silicon powder uncoated UN1398 | 4.3 | $H_2$ | — | IIC | T2 |
| Aluminium smelting by-products or Aluminium remelting by-products UN3170 | 4.3 | $H_2$ | — | IIC | T2 |
| Aluminium smelting/remelting by-products, processed | MHB(WF and/or WT and/or CR) | H2 | — | IIC | T1 |
| Ammonium nitrate UN1942 | 5.1 | — | — | | T4 |
| Ammonium nitrate-based fertilizer UN2067 | 5.1 | — | — | | T4 |
| Ammonium nitrate-based fertilizer UN2071 | 9 | — | — | | T4 |
| Ammonium nitrate-based fertilizer | - | — | — | | T4 |
| Ammonium nitrate-based fertilizer MHB | MHB(OH) | — | — | | T4 |
| Brown coal briquettes | MHB (CB and/or SH) | Dust, methane | IP55 | IIA | T4 |
| Coal | MHB (CB and/or SH and/or WF and/or CR) | Dust, methane | IP55 | IIA | T4 |
| Direct reduced iron (A) | MHB (SH and/or WF) | $H_2$ | — | IIC | T2 |
| Direct reduced iron (B) | MHB (SH and/or WF) | $H_2$ | — | IIC | T2 |
| Direct reduced iron (C) | MHB (SH and/or WF) | $H_2$ | — | IIC | T2 |
| Ferrophosphorus (including briquettes) | MHB (WF and/or WT) | $H_2$ | — | IIC | T1 |
| Ferrosilicon, with at least 25% but less than 30% silicon, or 90% or more silicon (including briquettes) | MHB (WF and/or WT) | $H_2$ | — | IIC | T1 |
| Ferrosilicon UN1408, with 30% or more but less than 90% silicon(including briquettes) | 4.3 | $H_2$ | — | IIC | T1 |
| Iron oxide, spent or sponge iron, spent UN1376 | 4.2 | Dust | IP55 | IIA | T2 |
| Seed cake, containing vegetable oil UN1386 | 4.2 | Hexane | — | IIA | T3 |
| Seed cake UN2217 | 4.2 | Hexane | — | IIA | T3 |

| Dangerous goods | IMO class | Dominant risk① | Protection against explosive dust atmosphere | Protection against explosive gas atmosphere | |
|---|---|---|---|---|---|
| | | | Degree of protection | Explosion group | Temperature class |
| Seed cakes and other residues of processed oily vegetables | MHB (SH) | Dust | IP55 | IIA | T3 |
| Silicomanganese (low-carbon) | MHB(WF and/or WT and/or TX) | $H_2$ | — | IIC | T1 |
| Solidified fuels recycled from paper and plastics | MHB (SH) | Combustible | IP55 | — | T3 |
| Sugarcane biomass pellets | MHB(CB and/or WF and/or WT and/or OH) | Combustible, dust | IP55 | IIA | T3 |
| Sulphur UN1350 (crushed lump and coarse grained) | 4.1 | Combustible, dust | IP55 | — | T4 |
| Zinc Ashes UN1435 | 4.3 | $H_2$ | — | IIC | T2 |
| Wood torrefied | MHB(CB and/or SH and/or CR) | Combustible, dust | IP55 | — | T3 |
| Wood pellets, containing additives and/or binders | MHB(WF) | Dust | IP55 | — | T3 |
| Wood pellets, not containing any additives and/or binders | MHB(OH) | Dust | IP55 | — | T3 |

Note: ① The term "risk" relates only to the risk of explosion due to dangerous goods and electrical appliances.

### 2.18.6 Pressurized protection and air locks

2.18.6.1 Spaces having openings into adjacent hazardous spaces or areas (such as the hazardous areas specified in 2.18.4.1(4) of this Section) may be regarded as non-hazardous spaces provided they are pressurized as indicated in the acceptable standards①.

2.18.6.2 Where air locks are fitted adjacent to a hazardous area specified in 2.18.4.1, the external spaces adjacent to the air locks and fitted with natural ventilation may be regarded as non-hazardous spaces.

### 2.18.7 Special requirements

2.18.7.1 If no details of the characteristics of the prospected cargo are available, or if a ship is intended for the carriage of all the materials defined in 2.18.1.2, the electrical equipment permitted in hazardous areas are to be in compliance with the following requirements:

— degree of protection provided by enclosure IP65;
— maximum surface temperature 85℃;
— explosion group IIC;
— temperature class T6.

### 2.18.8 Installation of electrical system in hazardous areas

2.18.8.1 If the electrical equipment installed is not suitable for use in areas where a risk of explosion exists, the equipment is to be capable of being disconnected and protected against unauthorized re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.

2.18.8.2 Cables are to be armoured or braided, or to be laid in metallic conduits.

2.18.8.3 Cable joints in cargo spaces are to be avoided where possible. Where joints are unavoidable, they are to be enclosed in explosion-proof metallic or high strength plastic junction boxes, or encapsulated crimp sleeve cable joints.

2.18.8.4 Cable penetrations of decks and bulkheads are to be sealed against the passage of inflammable gas or vapour.

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① See IEC Publication 60092-506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk.

### 2.18.9 Portable electrical appliances in hazardous areas

2.18.9.1 Portable electrical appliances, which must be used in hazardous areas for operation of the ship, are to be of a certified safe type suitable for such areas and except for intrinsically safe circuits, generally provided with their own power source.

### 2.18.10 Carriage of flammable liquids having a flashpoint below 23℃ in packaged form (classes 3, 6.1 and 8), aluminium smelting by-products or aluminium remelting by-products (UN 3170), aluminium smelting or remelting by-products processed (MHB), ferrosilicon (MHB) and ferrosilicon (UN 1408)

2.18.10.1 The bilge pipes with flanges, valves, pumps, etc., constitute a source of release and the enclosing spaces (e.g. pipe tunnels, bilge pump rooms, etc.) are to be classified as an extended hazardous area (comparable with Zone 2) unless these spaces are continuously mechanically ventilated with a capacity for at least six air changes per hour.

2.18.10.2 Except where the space is protected with redundant mechanical ventilation capable of starting automatically, equipment not certified for Zone 2 are to be automatically disconnected following loss of ventilation while essential systems such as bilge and ballast systems are to be certified for Zone 2.

2.18.10.3 Where redundant mechanical ventilation is employed, equipment and essential systems not certified for Zone 2 are to be interlocked so as to prevent inadvertent operation if the ventilation is not operational. Audible and visual alarms are to be provided at a manned station if failure occurs.