RULES

R014-2024

CHINA CLASSIFICATION SOCIETY

RULES FOR SHIPS USING NATURAL GAS FUELS

2024

Effective from 1 July 2024

Beijing

CONTENTS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 The Rules for Ships Using Natural Gas Fuels (hereinafter referred to as the Rules) apply to steel ships of 20 m or over in length which run on natural gas, except for liquefied gas carriers.

1.1.1.2 In addition to the Rules, ships using natural gas as fuel are to comply with the appropriate requirements of CCS Rules for Classification of Sea-going Steel Ships or Rules for Construction of Sea-going Ships Engaged on Domestic Voyages or Rules for the Construction of Inland Waterways Steel Ships of China Classification Society (hereinafter referred to as CCS Rules). Attention is to be paid for such ships to complying with the relevant requirements (if any) of the Administration of the flag State.

1.1.1.3 An existing ship, if its diesel engine(s) converted into a gas engine, is to be taken as a ship which has undergone a major conversion and is to comply with the relevant provisions of the flag State Administration, the Rules and CCS Guidelines for Implementation of Major Conversions of Ships. For the ships assigned a notation of DFDR(m) under CCS Guidelines for Natural Gas Fuel Ready Ships, the retrofit of their main engine(s) to dual fuel engine may not be regarded as major conversion unless the Administration determines otherwise.

1.1.1.4 Unless those expressly specified in this Chapter, the relevant terms used in the Rules are to have the meanings as defined in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk.

1.1.2 Definitions

1.1.2.1 **Accident** means an uncontrolled event that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

1.1.2.2 **Breadth of ship**, ***B***, is the breadth of ship defined in CCS Rules.

1.1.2.3 **Bunkering** means the transfer of liquid or gaseous fuel from land based or floating facilities into a ship's permanent tanks or the connection of portable tank to fuel supply system.

1.1.2.4 **Bunkering station** means a location or a space where a fuel bunkering system is installed, including bunkering connections, gas return connections (if any), related valves and control systems.

1.1.2.5 **Certified safe type** means electric equipment that is certified safe by the relevant authorities approved by CCS for operation in a flammable atmosphere based on a recognized standard[①].

1.1.2.6 **CNG** means compressed natural gas.

1.1.2.7 **Control station** means those spaces in which the ship's radio or main navigating equipment or emergency sources of power are located or where the ship's fire recording or fire control equipment is centralized and engine control rooms. Spaces where fire recording or fire control equipment is centralized are also considered to be a fire control station.

① E.g. IEC 60079 series, Explosive atmospheres and IEC 60092-502 Electrical Installations in Ships – Tankers – Special Features, or GB 3836 Explosive atmospheres.

1.1.2.8 **Design temperature for selection of materials** is the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks.

1.1.2.9 **Design vapour pressure P_0** is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.1.2.10 **Double block and bleed valve** means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

1.1.2.11 **Dual fuel engine** means internal combustion engines capable of operating on natural fuel and oil fuel simultaneously or operating only on oil fuel or natural gas.

1.1.2.12 **Double wall pipe** means pipes mainly used for supplying fuel to gas consumers and constructed with an inner pipe and an outer pipe. The space between the concentric pipes is full of inert gas at a pressure greater than the gas fuel pressure or ventilated according to the Rules.

1.1.2.13 **Enclosed space** means any space① within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.

1.1.2.14 **ESD** means emergency shutdown.

1.1.2.15 **Explosion** means a deflagration event of uncontrolled combustion.

1.1.2.16 **Explosion pressure relief** means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

1.1.2.17 **Fuel containment system** is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the fuel storage hold space.

The spaces around the fuel tank are defined as follows:

(1) Fuel storage hold space is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;

(2) Interbarrier space is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material;

(3) Tank connection space is a space surrounding all tank connections and tank valves.

Equipment, such as vaporizers or heat exchangers may be located in the tank connection space. Such equipment is considered to contain only potential sources of release, but not sources of ignition.

For example, these definitions refer to Figure 1.1.2.17 for type C independent tanks.

---

① Refer to the definitions in GB/T 22189 Electrical Installations in Ships – Special Features – Tankers or IEC 60092-502 Electrical Installations in Ships – Tankers – Special Features.

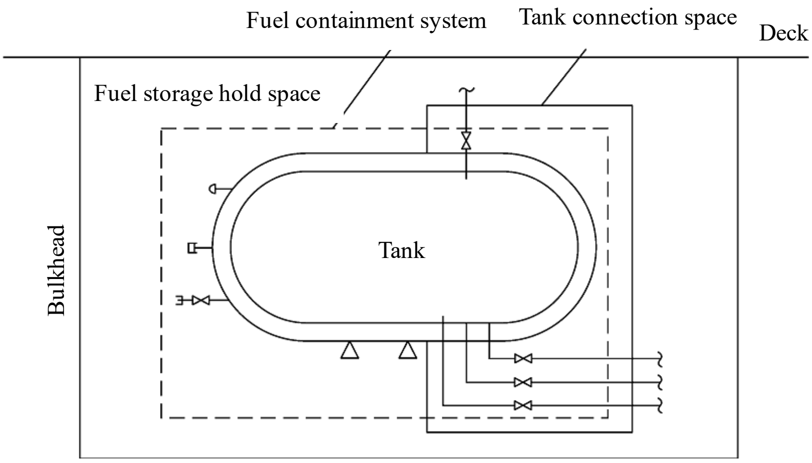


Figure 1.1.2.17 Example of Fuel Containment System in Enclosed Space

1.1.2.18 **Filling limit (FL)** means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

1.1.2.19 **Fuel preparation room** means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.

A tank connection space which has equipment such as vaporizers or heat exchangers installed inside is not regarded as a fuel preparation room. Such equipment is considered to only contain potential sources of release, but not sources of ignition.

1.1.2.20 **Gas** means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8℃.

1.1.2.21 **Gas consumer** means any unit within the ship using gas as a fuel.

1.1.2.22 **Gas engine** means a gas only engine or a dual fuel engine.

1.1.2.23 **Gas only engine** means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

1.1.2.24 **Gas valve unit space** means a gastight space or a valve box within which valves are fitted for controlling or adjusting the gas supply to the gas engine.

1.1.2.25 **Hazardous area** means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

Hazardous area zones are divided into:

(1) Hazardous area zone 0 is an area in which an explosive gas atmosphere is present continuously or is present for long periods;

(2) Hazardous area zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation;

(3) Hazardous area 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.

1.1.2.26 **High pressure** means a maximum working pressure greater than 1.0 MPa.

1.1.2.27 **Independent tanks** are self-supporting, do not form part of the ship's hull and are not essential to the hull strength.

1.1.2.28 **LEL** means the lower explosive limit.

1.1.2.29 **Length of ship, *L***, is the length of ship defined in CCS Rules.

1.1.2.30 **LNG** means liquefied natural gas.

1.1.2.31 **Loading limit (LL)** means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

1.1.2.32 **MARVS** means the maximum allowable relief valve setting.

1.1.2.33 **MAWP** means the maximum allowable working pressure of a system component or tank.

1.1.2.34 **Membrane tanks** are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure.

1.1.2.35 **Master gas valve** means an automatic stop valve located outside the engine room in the gas supply line to each engine and as close to the heater (if appropriate) as possible. The valve is to be of the fail-closed (closed on loss of power) type. For the installation of multi gas fuel engines, the master gas valve may be located either on gas manifold or on gas pipe branch to each gas engine.

1.1.2.36 **Non-hazardous area** means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

1.1.2.37 **Open deck** means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead.

1.1.2.38 **Portable tank** means a tank capable of being removed (e.g. lifted or rolled on/off) from ship for bunkering.

1.1.2.39 **Risk** is an expression for the combination of the likelihood and the severity of the consequences.

1.1.2.40 **Reference temperature** means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs).

1.1.2.41 **Secondary barrier** is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

1.1.2.42 **Semi-enclosed space** means a space[①] where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.

1.1.2.43 **Source of release** means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed.

For example, any valves, detachable couplings, pipe gaskets, compressors or pump seals within the gas system.

1.1.2.44 **Tank master valve** means a remote stop valve located in the gas supply line to each tank and as close to the tank outlet as possible. The tank master valve is to be of the fail-closed (closed on loss of power) type.

1.1.2.45 **Unacceptable loss of power** means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3.

---

① Refer to GB/T 22189 Electrical Installations in Ships–Special Features-Tankers or IEC 60092-502 Electrical Installations in Ships - Tankers–Special Features.

For sea-going ships engaged on domestic voyages and inland waterways ships, the unacceptable loss of power means a loss of power exceeding 60% of the total power essential to the propulsion and normal power supply.

1.1.2.46 **Vapour pressure** is the equilibrium pressure of the saturated vapour above the liquid, expressed in MPa absolute at a specified temperature.

1.1.3 Goals and functional requirements

1.1.3.1 The goal of the Rules is to provide a standard for the arrangements, construction and installation of machinery, equipment and systems related to LNG fuelled ships, to minimize the risk to the ship, personnel and to the environment.

1.1.3.2 The design and construction of a LNG fuelled ship are to comply with the following functional requirements for the above goal:

(1) The safety, reliability and dependability of the systems are to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery;

(2) The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated;

(3) The design philosophy is to ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power;

(4) Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment;

(5) Equipment installed in hazardous areas is to be minimized to that required for operational purposes and is to be suitable for the working environment and approved by CCS;

(6) Unintended accumulation of explosive, flammable or toxic gas concentrations is to be prevented;

(7) Gas system components are to be protected against external damages;

(8) Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions;

(9) It is to be arranged with safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system is to be designed to prevent venting under all normal operating conditions including idle periods.

(10) Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided;

(11) Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation;

(12) Fuel containment systems and machinery spaces containing source that might release gas into the space are to be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable;

(13) Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation;

(14) Fixed gas detection suitable for all spaces and areas concerned is to be arranged;

(15) Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided;

(16) Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy

the goal in terms of safety, availability and reliability;

(17) The technical documentation is to permit an assessment of the compliance of the system and its components with:

① the applicable rules, guidelines and design standards used; and

② the principles related to safety, availability, maintainability and reliability.

(18) A single failure in a technical system or component is not to lead to an unsafe or unreliable situation;

(19) Warning signs and protection measures are to be provided in the areas where all cryogenic equipment and pipes are located, to prevent persons from damage from low temperature due to unintended access or contact.

1.1.3.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release1[①] and potential ignition sources is not to:

(1) cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

(2) damage the ship in such a way that flooding of water below the main deck or any progressive flooding occurs;

(3) damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

(4) disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

(5) damage life-saving equipment or associated launching arrangements;

(6) disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;

(7) affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or

(8) prevent persons access to life-saving appliances or impede escape routes.

1.1.4 Class notations

1.1.4.1 Any LNG fuelled ship complying with the Rules and requesting to be classed with CCS may be added with the corresponding notation in Table 1.1.4.1 after the characters of classification specified by CCS.

Class Notations Table 1.1.4.1

Class notation	Description	
Natural Gas Fuel	Ships using natural gas as fuel	Ships with the main propulsion and/or auxiliary machinery using natural gas only or natural gas and oil fuel as fuel, other than liquefied gas carriers

① Double wall fuel pipes are not considered as potential sources of release.

1.1.5 Alternative design

1.1.5.1 Where the Rules require that a particular fitting, material, appliance, apparatus, item of equipment or type thereof is to be fitted or carried in a ship, or that any particular provision is to be made, or any procedure or arrangement is to be complied with, CCS may allow any alternative to be fitted or carried, or any other provision to be made in that ship, if it is satisfied by trial thereof or otherwise that such alternative, or provision, is at least as effective as that required by the Rules.

1.1.5.2 CCS is not to allow operational methods or procedures to be applied as an alternative to particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by the Rules.

1.1.6 Risk assessment

1.1.6.1 The goal of risk assessment is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

1.1.6.2 Risk assessment needs only be conducted where explicitly required by the Rules.

1.1.6.3 The risks are to be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock are as a minimum to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of CCS.

1.1.6.4 Risk assessment may be conducted referring to ANNEX 1 of the Rules.

1.1.7 References in the Rules

1.1.7.1 Every reference to the articles of related documents constitutes the ones of the Rules. For references undated, their latest versions are applicable to the Rules.

Section 2 PLANS AND DOCUMENTATION

1.2.1 Plans and documents for approval

1.2.1.1 In addition to those specified in CCS Rules, the following plans and documents are to be submitted in triplicate to CCS for approval:

(1) Ship arrangements

① machinery spaces, accommodation spaces, service spaces and control stations;

② fuel containment systems;

In addition, tank supporting and fixed installations are considered for portable liquefied gas tanks.

③ fuel preparation rooms, if any;

④ fuel bunkering systems, including bunkering connections;

⑤ accesses, vent pipes and other openings of fuel tank spaces and fuel tank connection spaces;

⑥ ventilation pipes, doors and openings of fuel preparation rooms and other gas hazardous spaces;

⑦ entrances, air inlets and opening of accommodation spaces, service spaces and control stations;

⑧ locations and structures of air locks (if any);

⑨ gastight bulkhead penetration (if any);

⑩ instruction of drip tray or other protection means;

⑪ hazardous area zones classification.

(2) Piping systems

① details or instruction of the gas fuel piping, including pressure relief valves and vent pipes;

② technical documents of the branch pipes, return pipes, bends, expansion joints, bellows or similar devices;

③ plans and instruction of the flanges, valves and other devices;

④ technical documents of the materials, welding, post-weld heat treatment and non-destructive testing of gas piping;

⑤ technical documents of pressure testing (strength and tightness test) of gas piping;

⑥ functional test guidelines for all piping, including valves, fittings and equipment relating to gas (liquid or vapour) operation;

⑦ technical documents of electrical bonding of piping;

⑧ technical documents of the arrangements for removing fuel from fuel bunkering pipes before the bunkering joint is cut off;

⑨ cooling water systems or hot water systems relating to gas fuel systems, if any;

⑩ arrangement and instruction of gas freeing and inert gas purging systems;

⑪ arrangement of bilge and drainage systems for the fuel preparation room and tank connection space (if any);

⑫ capacity calculation of piping pressure relief valve;

⑬ In addition, detailed plans or description of connecting lines for fuel supply, venting and heating medium supply to heat exchanger (if fitted), in case of portable liquefied gas tank.

(3) Ventilation systems

① arrangement and instruction (capacity calculations etc.) of mechanical ventilation systems in hazardous areas, including the capacity and arrangement of fans and motors thereof, plans of the moving parts and covers of fans and material document thereof; and

② arrangement of double wall pipes (air ducts).

(4) Fire-fighting appliances and systems

① arrangement and instruction (e.g. capacity calculation) of water spray systems, including pipes, valves, nozzles and fittings;

② fire detection system and arrangement;

③ structural fire protection arrangement of fuel storage hold space and tank connection space and their vent pipes, bunkering stations (if applicable); and

④ arrangement of dry powder fire-extinguishing arrangements.

(5) Electrical systems

① arrangement of electrical installations in the hazardous area, including all electrical equipment thereof and the followings:

(a) type of protection, explosion group and temperature class;

(b) degree of protection;

(c) hazardous classification of the installation area.

② check data[①] of intrinsically safe circuits, including voltage, current, inductance and capacitance;

③ list of certified explosion-proof equipment.

(6) Control, monitoring and safety systems

① gas detection and alarm systems and their arrangement, including probes, alarm arrangements and alarm set points;

② gas tank monitoring and control systems and their arrangement, including sensors, alarm set points;

③ gas compressor control and monitoring systems and their arrangement, if any;

④ electrical schematic diagram and monitoring lists of the gas fuel bunkering and supply system;

⑤ in addition, detailed plans or description of tank control, monitoring and safety system and its connection to ship, in case of portable liquefied gas tank.

(7) Test guidelines and procedures

① mooring and sea trials procedure relating to gas fuel, e.g. functional tests for all gas piping and their valves, fittings and relevant equipment.

Note: Actual plans/documents may have a name different from those mentioned above, but they are to show the requirements above.

(8) Inspection /survey plans

① inspection/survey plans for fuel containment systems, see 4.2.1.8 of Chapter 4 of the Rules.

1.2.2 Plans and documents for information

1.2.2.1 The following plans and documents are to be submitted to CCS in triplicate for information:

(1) Thermal stress analysis of piping with a design temperatures lower than minus 110°C;

(2) Insulation arrangement of low temperature piping;

(3) Analysis report of risks concerned (if applicable);

(4) In addition, specifications of connecting hose and connections, in case of portable liquefied gas tank.

1.2.3 Plans and documents kept on board

1.2.3.1 In addition to those specified in CCS Rules, the following documents are to be kept on board:

(1) One gas fuel system operational booklet, which is to comply with 14.2.4.1 of the Rules;

(2) One periodic testing plan for instruments and equipment of gas control, monitoring and safety system, which covers test intervals, requirements and direction and so on. In case of the instruments and equipment for emergency shutoff mentioned in Table 12.4.2 and Table 12.4.3, Chapter 12 of the Rules, the test interval is not to exceed 6 months, and not to exceed 12 months for the remaining instruments and equipment.

① The intrinsically safe circuits are to be so installed that the inductance and capacitance of their equipment, including cables, do not exceed the listed values of the associated apparatus, and the values of permissible input voltage, input current of each intrinsically safe apparatus is to be greater than or equal to the listed values respectively of the associated apparatus. Refer to IEC60079-14 Explosive Atmospheres-PART 14: Electrical Installations Design, Selection and Erection or equivalent standards.

Section 3 PRODUCT INSPECTIONS

1.3.1 General requirements

1.3.1.1 Product inspections are to comply with the relevant requirements for LNG fuelled ships of CCS Rules, regulations and product inspection guidelines.

Section 4 SHIP SURVEYS

1.4.1 General requirements

1.4.1.1 All survey programmes, survey methods, types of survey, intervals between the surveys, survey conditions, preparations before survey, survey and testing requirements and preservation of the plans and documents, certificates, records and reports, etc., are to be in compliance with CCS Rules for Classification of Sea-going Steel Ships or Regulations for Classification of Sea-going Ships Engaged on Domestic Voyages for sea-going ships, or in compliance with CCS Regulations for Classification of Inland Waterways Ships for inland waterways ships.

1.4.2 Surveys during construction

1.4.2.1 In addition to CCS Rules, surveys during construction are to cover the following items:

(1) Installation and testing of gas engines, boilers (if any) and gas turbines (if any);

(2) Installation and testing of fuel containment systems, referring to the inspection requirements for liquefied gas tanks of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk and regulations for classification;

(3) Installation and testing of fuel bunkering systems;

(4) Installation and testing of fuel supply systems, including heat exchangers;

(5) Installation and testing of ventilation systems of machinery spaces containing gas engine(s), fuel storage hold spaces, double walled pipes, tank connection spaces (if any) and fuel preparation rooms (if any);

(6) Installation and testing of remote closing devices of gas engines;

(7) Check of the locations and quantity of gas detectors, and testing of gas detection and alarm systems;

(8) Installation and testing of fuel bunkering systems and fuel supplying systems;

(9) Confirmation and safety checking of explosion-proof equipment or anti-ignition equipment. Where the safety of explosion-proof electrical equipment depends on the actions of protection arrangement (e.g. overload protective relay) and/or alarm arrangement (e.g. no volt alarm of pressurized equipment), a performance test is to be carried out for such arrangement to verify the accuracy of their actions and alarm setting values;

(10) Confirmation of the ventilation ability of spaces protected by positive pressure, testing of the clarification time at the lowest ventilation discharge and recording in the relevant document, and verification of the safety actions (shutoff and/or alarm) to carry out at abnormal pressure;

(11) Performance test of ventilation plants for spaces with a hazard level depending on mechanical ventilation, the ventilation is to be sufficient and the ventilation system fault alarm is to be in order;

(12) Confirmation of correct installation of equipment and cables of intrinsically safe circuits;

(13) Installation and testing of fire protection, detection and extinction arrangements;

(14) Check of gas fuel system operational manual.

1.4.3 Surveys after construction

1.4.3.1 Annual surveys: In addition to the survey items in CCS Rules (if applicable), the followings are to be covered with insulation remained and any evidence of deterioration or dampness of the insulation is to be investigated:

(1) Fuel containment systems

① verifying that the nameplate of independent tanks of type C is clear, solid and the contents are full;

② examining whether the tank level indicators are in working condition and the high level alarms and high level self-closing systems are in normal working condition;

③ external examination of tanks and pressure relief valves;

④ examining whether the tank pressure, liquid level and temperature indicators and control and alarm means are in order;

⑤ external examination of tanks including secondary barriers if fitted and their accessibility. Examination of any erosion, corrosion, scratch, indent, deformation, weld defect, frosting or condensation of the shell of independent tanks of type C;

⑥ examining visually the interface of the main body of tanks for weld cracks;

⑦ verifying that the safety operation procedure of tanks is kept on board, including safety control of master valves, liquid volume tables, emergency disconnecting of pressure relief valves, precooling for bunkering;

⑧ general examination of fuel storage hold spaces;

⑨ examination and testing of installed bilge alarms and means of drainage of compartments;

⑩ testing of the remote and local closing of installed tank master valves.

(2) Checking heat exchangers to confirm that its operation and heating capacity comply with the technical specifications;

(3) Verification whether the sealing device of tank connection spaces and gas valve unit spaces is in order, and internal examination of tank connection spaces;

(4) Examining whether the doors, side scuttles and windows of end bulkheads of superstructures and deckhouses facing hazardous areas are in good conditions;

(5) Examining whether the shutdown devices and other means (if any) used to close any special enclosed space to protect the crew in case of fuel leakage are in normal working condition;

(6) Examining whether the portable ventilation (if any) used in the space which is not generally entered are in normal working condition;

(7) Examination of portable/fixed drip trays and insulation for the protection of hull structure in case of leakage;

(8) Examining the ventilation systems (including fitted portable ventilation) of the spaces containing fuel storage, fuel bunkering and fuel supply arrangements/components or associated systems, including air locks, pump rooms, compressor rooms, fuel preparation rooms, fuel valve rooms, control rooms and spaces containing gas burning equipment. Where alarms are fitted, such as differential pressure and loss of pressure alarms, they are to be operationally tested as far as practicable;

(9) Verification of the satisfactory operation of control, monitoring and automatic shut-down systems,

including the testing of manual emergency shutdown function, as far as practicable of fuel supply and bunkering systems;

(10) Checking piping, hoses, emergency shut-down valves, remote operating valves, relief valves, machinery and equipment for fuel storage, bunkering, and supply such as venting, compressing, refrigerating, liquefying, heating, cooling or otherwise fuel handling provisions, as far as practicable. Special attention is to be given to the pipe expansion joints and supports. Means for inerting is to be examined. Confirming the satisfactory stopping of pumps and compressors upon emergency shut-down of the system, as far as practicable;

(11) Examining the penetrations of electrical equipment and bulkheads/decks within the hazardous areas, including access openings to hazardous areas, for continued suitability for their intended service and installation areas, and checking the maintenance repair record;

(12) Examining the satisfactory operational condition of gas and other leakage detection equipment (including indicators and alarms) in spaces containing fuel storage, bunkering and supply equipment/components or associated systems, and checking the satisfactory recalibration of gas detection system according to the manufacturers' recommendations;

(13) Confirming that no substantial change has been made to the fireproof structure and arrangement of fuel tank, bunkering station and machinery space containing engine(s) etc.;

(14) Examining fire detection and extinction systems, and testing one main fire-fighting pump;

(15) Examining whether water-spraying systems are in order;

(16) Examining whether dry powder fire-extinguishing systems are in order;

(17) Check of gas fuel system operational manuals;

(18) Confirming electrical earthing of pipes and tanks to the hull;

(19) Checking the logbooks and operating records to confirm the satisfactory operation of gas detection systems, fuel supply/gas systems etc. The hours per day of reliquefaction plants (if fitted) and gas combustion units (if fitted), as applicable, the boil-off rate and nitrogen consumption (for membrane containment systems) are to be considered together with gas detection records;

(20) Confirming that the manufacturer/builder instructions and manuals covering the operation, safety and maintenance requirements and occupational health hazards relating to fuel storage, fuel bunkering, and fuel supply and fuel utilization are kept on board the ship;

(21) Operational test, as far as practicable, of the shutdown of ESD protected machinery spaces;

(22) Examining the electrical bonding arrangement in hazardous areas, including bonding straps;

(23) Fuel bunkering systems

①examination of bunkering stations and fuel bunkering systems;

②verification of the satisfactory operation of fuel bunkering control, monitoring and shut-down systems.

(24) Examining fuel supply systems under working conditions as far as practicable:

① verification of the satisfactory operation of control, monitoring and shut-down of fuel supply systems;

② testing of the remote and local closing of master fuel valve of each engine room.

1.4.3.2 Intermediate surveys: In addition to the survey items (if applicable) in CCS Rules and 1.4.3.1 of this Chapter, the following items are to be covered:

(1) Confirming the provision of spares for the fans used for mechanical ventilation of hazardous spaces;

(2) Visual examination of the pressure, temperature and liquid level instruments related to gas systems, and checking the pressure, temperature and liquid level by contrast. A simulation test may be accepted to inaccessible sensors, including alarm and safety functional tests;

(3) Testing of the vacuum rate[①] of vacuum insulated type C independent tanks;

(4) Electrical equipment: ground protection (checking of earthing contact), integrity of flame-proof enclosures, damage of cable jackets, functional tests of pressurized apparatuses and the related alarm devices for the electrical equipment within hazardous areas as far as possible, testing of shutoff the power supply for non-certificated explosion-proof electrical equipment in the spaces protected by air locks (if any), and measurement of insulation resistance;

(5) Safety systems: Gas detectors, temperature sensors, pressure sensors, level indicators and other equipment providing input to the fuel safety system are to be randomly tested to confirm their satisfactory operating condition. Verifying the satisfactory response of fuel safety systems under failure conditions.

1.4.3.3 Special surveys: In addition to the survey items (if applicable) in CCS Rules and 1.4.3.2 of this Chapter, the following items are to be covered:

(1) Fuel containment systems

① The tanks fitted with manholes are to be opened up to visually examine the followings:

(a) connection of swashplate (if any) to tank body, cracks in way of connecting welds, loosening of fixed bolts, crack, break or breakaway of swashplate;

(b) crack, break or loosening in way of the connection of fixed brackets of tank vapour pipes, liquid meters to the tank body.

② Gas-tightness testing of tanks together with vapour and liquid pipes thereof, and the test medium is to be dry and clean nitrogen or air. Air is not permitted to use as test medium unless gas composition in tanks is qualified before the gas-tightness test;

③ hydraulic testing of tanks together with vapour pipes and liquid pipes thereof. The hydraulic test may be dispensed with, provided that the plate and tower structures of the tank supporting, bearing and pipe connecting pieces and sealing devices of penetrations in the deck are in order, the working of gas monitoring systems is satisfied and the navigation records declare no abnormal operation;

④ all valves and cocks directly connecting to the tank are to be opened upon for examination, and where practicable the internal examination is to be carried out for connecting pipes;

⑤ the tank's pressure relief valves are to be opened out for examination, calibration and functional testing. If non-metallic membranes are provided in their main or pilot valves, such non-metallic membranes are to be replaceable;

⑥ In the case of tanks covered by insulation, enough insulation is to be removed, in particular, in way of connections and supporting, to ensure that the tank is in order;

⑦ tanks are to be examined in accordance with an approved survey plan. In developing the inspection/survey plan according to 4.2.1.8 of the Rules, the requirements for the survey of LNG fuel containment systems are to be in accordance with the relevant requirements of A2.3.2.4, Chapter A2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk or A1.3.3.4, Chapter A1, PART TWO of CCS Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk, except as noted below:

(a) visual examination of the tank insulation and supports. Non-destructive testing may be required

① The testing method may refer to GB/T 18443.2 Testing Method of Performance for Vacuum Insulation Cryogenic Equipment - Part 2: Vacuum Degree Measurement.

if conditions raise doubt to the structural integrity;

（b）vacuum insulated independent tanks of type C without access openings need not be examined internally. Where fitted, the vacuum monitoring system is to be examined and records are to be reviewed.

(2) Piping systems

①All piping for fuel storage, fuel bunkering and fuel supply, such as venting, compressing, refrigerating, liquefying, heating storing, burning or other fuel treatment modes, and liquid nitrogen installations are to be examined. Removal of insulation from the piping and opening for examination may be required, and special examination is to be carried out to seals. Where deemed suspect, a hydrostatic test to 1.25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing;

② Pressure relief valves for the fuel supply and bunkering piping are to be opened for examination, adjustment and function test. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since crediting of the previous Special Survey;

③ All emergency shut-down valves, check valves, block and bleed valves, master gas valves, remote operating valves, isolating valves for pressure relief valves in the fuel storage, fuel bunkering and fuel supply piping systems are to be examined and proven operable. A random selection of valves is to be opened for internal examination.

(3) The pressure/vacuum relief valves, rupture discs and other pressure relief devices for interbarrier spaces and hold spaces are to be opened, examined, tested and readjusted as necessary, depending on their design;

(4) Fuel handling equipment

① fuel pumps, compressors, process pressure vessels, inert gas generators, heat exchangers and other components used in connection with fuel handling are to be examined as required in CCS Rules for periodical survey of machinery;

② heat exchangers are to be opened up for examination and tested for performance;

③ examination of inert gas generators to confirm that the generated inert gas is compliance with the technical specifications and the generators are in order;

④ a general examination of inert gas distributing valves and pipes, an internal and external examination of pressure vessels for storage of inert gas and a special survey for securing arrangements, and confirmation of the satisfactory condition of pressure relief valves;

⑤ each compressor is to be opened up to examine the moving and fixed parts, valves, valve seat rings, gland covers, relief devices, filters and lubricating equipment, etc. Where the Surveyor is satisfied to the alignment and abrasion, the lower bearing and crankcase seal glands may not be opened up for examination.

(5) Electrical equipment

① examination of electrical equipment, including the physical conditions of electrical cables and supports, intrinsically safe, explosion proof, or increased safety features of electrical equipment;

② functional testing of pressurized equipment and associated alarms;

③ testing of systems for de-energizing electrical equipment which is not certified for use in hazardous areas, such as those mentioned in 9.2.2.2 (7);

④ an electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces is to be carried out.

(6) Safety systems

① testing to confirm that gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system are in order;

② verification of the satisfactory response of fuel safety systems under failure conditions;

③ pressure, temperature and level indicating equipment are to be calibrated in accordance with the manufacturer's requirements.

(7) Removing the shaft seals on gastight bulkheads and examining the sealing device;

(8) Gas engines, in addition to the special survey items for diesel fuel engines specified in CCS Rules, the following items are to be covered: general inspections of the ducts or cover enclosure of gas pipes, inspections of discharge or inerting equipment for pipes, and operating testing of gas fuel engines at work.

CHAPTER 2 SHIP DESIGN AND ARRANGEMENTS

Section 1 GENERAL PROVISIONS

2.1.1 Goal

2.1.1.1 The goal of this Chapter is to provide technical requirements for safe locations, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

2.1.2 Functional requirements

2.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1) to (3), (5) , (6), (8), (12) to (15), (17) and (19). In particular the following apply:

(1) Fuel tanks are to be located in such a way that the probability for the tanks to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;

(2) Fuel containment systems, fuel piping and other fuel sources of release are to be so located and arranged that released gas is lead to a safe location in the open air;

(3) The accesses or other openings to spaces containing fuel sources of release are to be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;

(4) Fuel piping is to be protected against mechanical damage;

(5) Propulsion and fuel supply systems are to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power;

(6) The probability of a gas explosion in a machinery space with gas consumers is to be minimized;

(7) Unless designed with the strength to withstand the worst case explosion, the exhaust systems of the ship's engines are to be fitted with suitable pressure relief devices;

(8) Passenger ships are to be fitted with physical isolation or other equivalent means to prevent any passenger or unauthorized personnel from entry into the fuel storage hold space and bunkering station during operation of the ship.

Section 2 ARRANGEMENT OF FUEL TANKS

2.2.1 General requirements

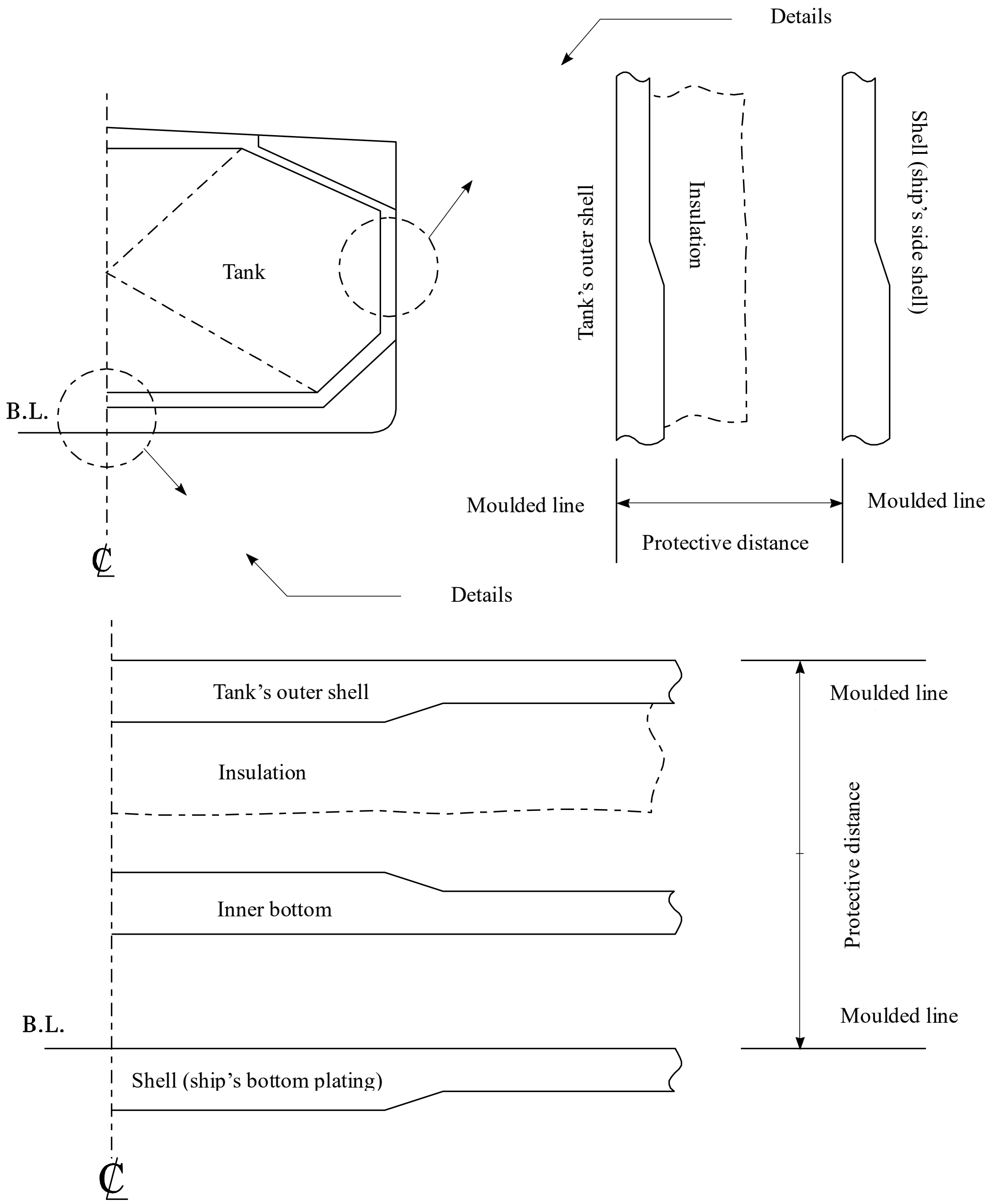
2.2.1.1 Fuel storage tanks are to be protected against mechanical damage.

2.2.1.2 Fuel storage tanks and/or equipment located on open deck are to be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

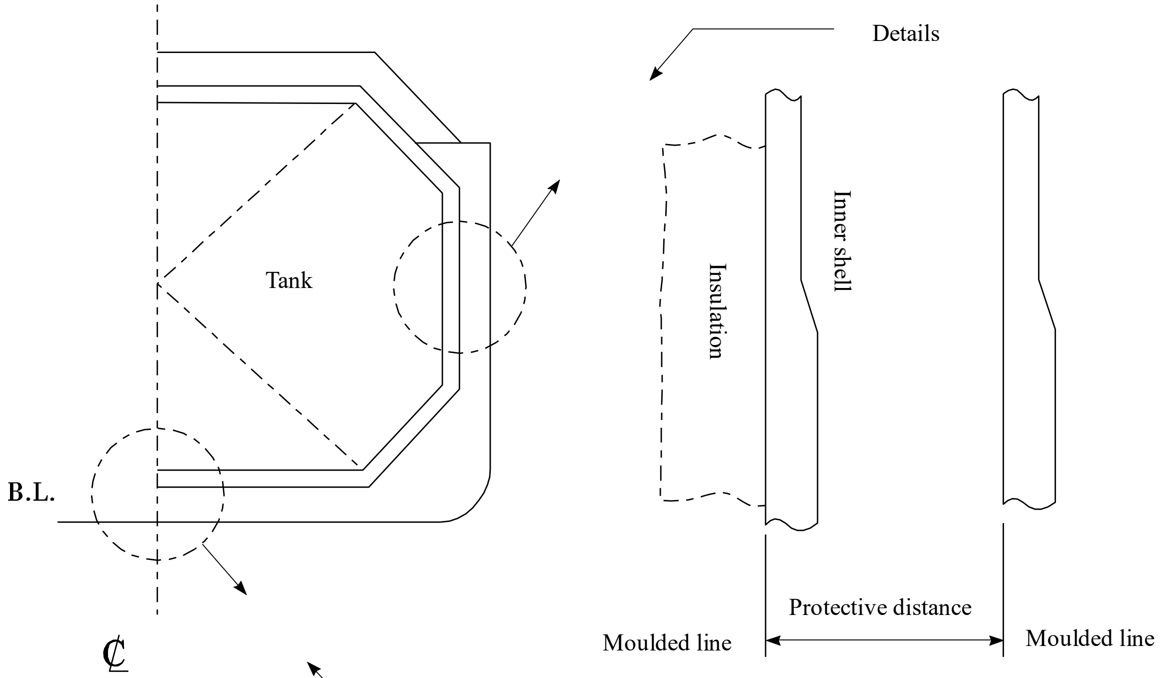
2.2.1.3 Fuel tanks are to be protected from external damage caused by collision or grounding in the following way:

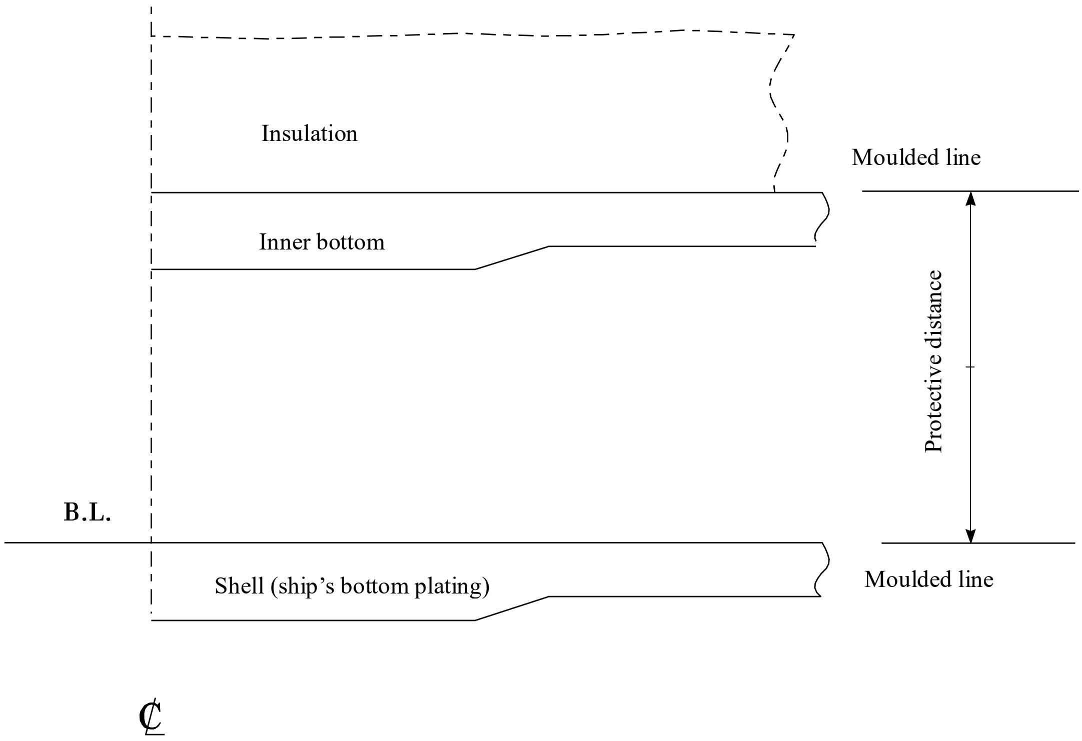
(1) The boundaries of each fuel tank are to be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves;

(2) For independent tanks, the protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks, the distance is to be measured to the bulkheads surrounding the tank insulation. For the protective distances of different tanks, see Figure 2.2.1.3 (2);

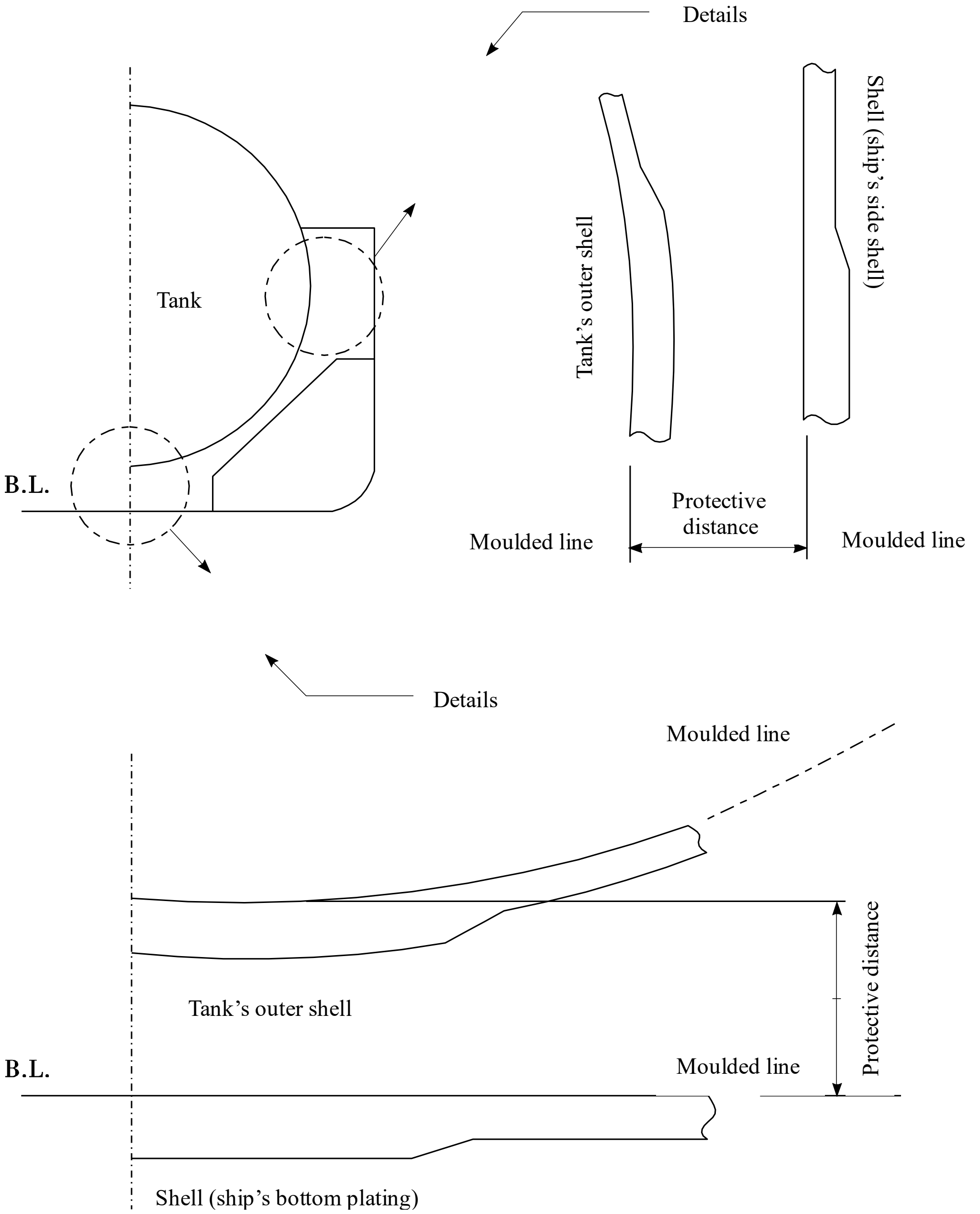


(a) Independent Prismatic Tanks





(b) Membrane Tanks



（c）Type C Independent Tanks

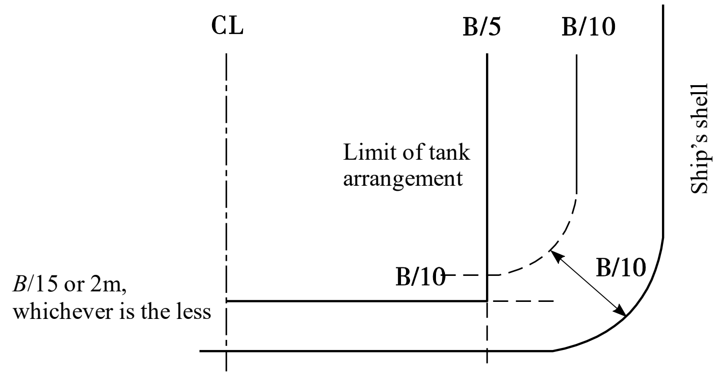
Figure 2.2.1.3(2) The Protective Distances of Different Tanks

(3) For sea-going ships:

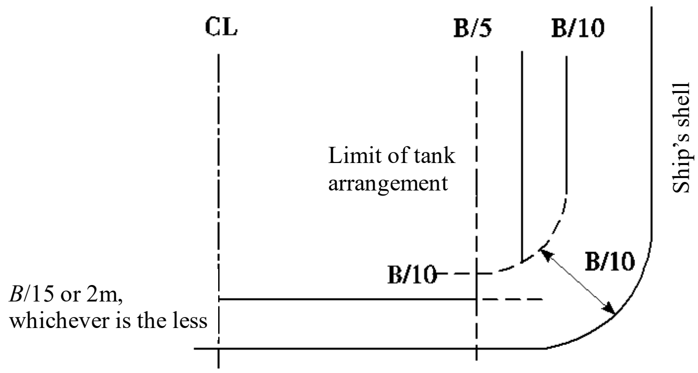
① the fuel tanks are to be located at a minimum distance of *B*/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught; where, *B* is the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught);

② in no case, the boundary of the fuel tank is to be located closer to the shell plating or aft terminal of the ship than as follows:

(a) for passenger ships: *B*/10 but in no case less than 0.8 m. However, the distance need not be greater than $B/15$ or 2 m whichever is the less for the area located between the middle line of the ship and the distance of $B/5$ or 11.5 m (whichever is the less) required in ①, referring to Figure 2.2.1.3 (3);



(a) The Protective Distances obtained by an Deterministic Approach



(b) The Protection Distances by a Probability Approach

Figure 2.2.1.3(3) The Arrangement of Passenger Ship's Tanks

(b) For cargo ships:

for V_c below or equal to 1,000 m^3, 0.8 m;

for 1,000 $m^3 < V_c <$ 5,000 m^3, 0.75 + V_c×0.2/4,000 m;

for 5,000 $m^3 \le Vc <$ 30,000 m^3, 0.8+V_c/25,000 m; and

for $V_c \ge$30,000 m^3, 2 m,

where:

V_c corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

③ the lowermost boundary of the fuel tank(s) is to be located above the minimum distance of B/15 or 2.0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.

(4) For inland waterways ships:

① the fuel tanks are to be located at a minimum distance of $B/10$ or 1.0 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the full load line draught;

② In no case, the boundary of the fuel tank(s) is to be located closer to the shell plating or aft terminal of the ship than 0.8 m.

(5) For multihull ships, the value of B may be specially considered;

(6) The fuel tank(s) is (are) to be abaft a transverse plane at 0.08L measured from the forward perpendicular for passenger ships, and abaft the collision bulkhead for cargo ships;

(7) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location requirements may be specially considered in accordance with 1.1.5 of the Rules.

2.2.1.4 As an alternative to 2.2.1.3 (3) ① of this Section, the following calculation methods may be used for sea-going ships:

(1) The value f_{CN} calculated as described in the following is to be less than 0.02 for passenger ships and 0.04 for cargo ships;

(2) The f_{CN} is calculated by the following formulation:

$$f_{CN}=f_l \times f_t \times f_v$$

where:

f_l is calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1. The value of x_1 is to correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x_2 is to correspond to the distance from the aft terminal to the foremost boundary of the fuel tank.

f_t is calculated by use of the formulations for factor r contained in SOLAS regulation II-1/7-1.1.2, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is:

$$f_t = 1 - r(x_1, x_2, b)$$

where:

When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline, the value of b is to be taken as 0.

f_v is calculated by use of the formulations for factor v contained in SOLAS regulation II-1/7-2.6.1.1 and reflects the probability that the damage is not extending vertically above the lowermost boundary of the fuel tank. The formulations are:

$f_v = 1.0 - 0.8\frac{H-d}{7.8}$, if $(H-d)$ is less than or equal to 7.8 m. f_v is not to be taken greater than 1.

$f_v = 0.2 - 0.2\frac{(H-d)-7.8}{4.7}$, in all other cases. f_v is not to be taken less than 0.

where:

H ——the distance from baseline, in m, to the lowermost boundary of the fuel tank;

d ——the deepest draught (summer load line draught), in m.

(3) In case of arrangements of more than one non-overlapping fuel tank located in the longitudinal direction, f_{CN} is to be calculated in accordance with 2.2.1.4 (2) of this Section for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for f_{CN} obtained for each separate tank;

(4) In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, f_{CN} is to be

calculated on both starboard and port side and the average value is to be used for the assessment.

2.2.1.5 When fuel is carried in a fuel containment system requiring a complete or partial secondary barrier,

(1) fuel storage hold spaces are to be segregated from the sea by a double bottom; and

(2) the ship is also to have a longitudinal bulkhead forming side tanks.

2.2.1.6 For passenger ships, fuel tanks, if located on the weather deck, and tank connection spaces are to be at least 10 m away from embarkation stations and assembly stations for survival crafts and marine evacuation systems and escape routes. If this is impracticable, effective insulation, such as water curtains, fire divisions or suitable screens, is to be provided between the fuel tanks and tank connection spaces and the above locations, to prevent the persons in such locations from damage due to a fire or leakage.

2.2.1.7 For ships carrying dangerous goods in packaged form, the distance between dangerous goods and gas supply systems is to comply with the requirements for segregation of such type of dangerous goods to dangerous substances of class 2.1 of International Maritime Dangerous Goods Code (IMDG Code).

2.2.1.8 For ships carrying dangerous chemicals in bulk and ships carrying dangerous solid goods in bulk, the fuel tanks are to be so arranged as to prevent any hazardous reaction between LNG and the goods intended to be carried. If the fuel tank is located in an enclosed space, a cofferdam is to be provided between the tank and the adjacent dangerous goods space. If the fuel tank is reserved for arrangement on open deck or semi-enclosed area, a tank connection space is to be provided.

2.2.1.9 For passenger ships required to meet the requirements for safe return to port, the tanks are to be arranged according to the following requirements:

(1) Where a gas-only fuel installation is used, the gas is to be supplied from two or more tanks having a similar volume. Where such tanks are located in enclosed spaces, they are to be arranged in independent compartments with watertight divisions between them, and a cofferdam is to be fitted between the fuel storage hold spaces. Where no cofferdam is fitted, an ‘A-60’ class division is to be provided between the fuel storage hold spaces. Where such tanks are located on the weather deck, they are to be away from each other as far as practicable and effective means are to be provided to prevent effects on other tanks due to a fire in one tank.

(2) Where a dual fuel installation is used, a liquid tank, empty tank, sanitary and similar space is to be as a cofferdam to separate the adjacent compartments in which the fuel tank and the oil tank are separately located. Where no cofferdam is fitted, an ‘A-60’ class division is to be provided between the fuel storage hold space and the oil tank space.

Section 3 LOCATION AND DIVISION OF SPACES

2.3.1 Machinery space concepts

2.3.1.1 In order to minimize the probability of a gas explosion in a machinery space with gas consumer, one of these two alternative concepts may be applied:

(1) Gas safe machinery spaces: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe. In a gas safe machinery space, a single failure cannot lead to release of fuel gas into the machinery space.

(2) ESD-protected machinery spaces: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency

shutdown (ESD) of non-safe equipment (ignition sources) and machinery are to be automatically executed while equipment or machinery in use or active during these conditions is to be of a certified safe type.

In an ESD protected machinery space, a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures.

Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are to be covered by explosion pressure relief devices and ESD arrangements.

2.3.2 Gas safe machinery spaces

2.3.2.1 A single failure within the fuel system is not to lead to a gas release into the machinery space.

2.3.2.2 All fuel piping within machinery space boundaries is to be enclosed in a gastight enclosure as specified in 6.4.1.1.

2.3.3 ESD-protected machinery spaces

2.3.3.1 ESD protection is to be limited to machinery spaces that are certified for periodically unattended operation.

2.3.3.2 Explosion-proof means are to be provided to prevent damage to the external of the machinery space and to ensure redundant power supply. The following arrangement is to be provided but may not be limited to:

(1) gas detector;

(2) shutoff valve;

(3) redundancy; and

(4) efficient ventilation.

2.3.3.3 Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

(1) Engines for generating propulsion power and electric power are to be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces;

(2) The gas machinery space is to contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function;

(3) A fixed gas detection system arranged to automatically shutdown the gas supply, and disconnect all electrical equipment or installations not of a certified safe type, is to be fitted.

2.3.3.4 Distribution of engines between the different machinery spaces is to be such that shutdown of fuel supply to any one machinery space does not lead to an unacceptable loss of power.

2.3.3.5 ESD-protected machinery spaces separated by a single bulkhead are to have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

2.3.3.6 ESD-protected machinery spaces are to be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

2.3.3.7 The ventilation system of ESD-protected machinery spaces is to be arranged in accordance with 10.3.1 of the Rules.

2.3.4 Location and protection of fuel piping

2.3.4.1 Fuel pipes are not to be located less than 800 mm from the ship side.

2.3.4.2 Fuel pipes are not to be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations.

2.3.4.3 Fuel pipes led through Ro-Ro spaces, special category spaces and on open decks are to be protected against mechanical damage.

2.3.4.4 Gas fuel piping in ESD-protected machinery spaces are to be located as far as practicable from the electrical installations and tanks containing flammable liquids.

2.3.4.5 Gas fuel piping in ESD-protected machinery spaces are to be protected against mechanical damage.

2.3.5 Fuel preparation rooms

2.3.5.1 Fuel preparation rooms are to be located on an open deck, unless those rooms are arranged and fitted in accordance with the requirements for tank connection spaces.

Where a fuel preparation room is not located on an open deck, only the followings are to be applied to the above requirements:

(1) The requirements for bolted hatches in 2.3.8.3 of this Section and the requirements for hazardous area zone 2 in 9.2.2.3 (2) of the Rules do not apply to a fuel preparation room located below deck, unless it may be defined as a tank connection space according to the definition of 1.1.2.17 (3) of the Rules.

(2) Fuel preparation rooms, if having an opening to other enclosed space (non-hazardous space) of the ship, are to be fitted with an airlock according to 2.3.8.2 of this Section.

(3) The airlock may be dispensed with for fuel preparation spaces having an independent access direct from an open deck or from a semi-enclosed space on deck. In such case, the areas outside the opening are to be classified as an hazardous zone according to 9.2.2.2 (4) and 9.2.2.3 (1) of the Rules.

(4) Where fuel preparation rooms handle liquid fuel, the provisions for bilge wells in 12.1.3.1 of the Rules are to be applicable only to such rooms below deck.

2.3.5.2 A fuel preparation room located on open deck is to comply with the following requirements:

(1)The fuel preparation room is to safely contain cryogenic leakages;

(2)The material of the boundaries of the fuel preparation room is to have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection;

(3)The fuel preparation room is to be arranged to prevent surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of cryogenic liquids;

(4)The fuel preparation room is to be designed to withstand the maximum pressure build up during such a leakage defined in 2.3.5.2 (2) of this Section. Alternatively, a pressure relief device to a safe location (mast) is to be provided.

2.3.6 Bilge systems

2.3.6.1 Bilge systems installed in areas where LNG can be present are to be segregated from the bilge system of other spaces.

2.3.6.2 Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure are to be provided. The bilge system is not to lead to pumps in safe spaces. Means of detecting such leakage is to be provided.

2.3.6.3 The hold or interbarrier spaces of type A independent tanks are to be provided with a drainage system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.

2.3.7 Drip trays

2.3.7.1 Drip trays are to be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is effected from a spill is necessary.

2.3.7.2 Drip trays and their pipes are to be made of suitable material.

2.3.7.3 The drip tray is to be connected to the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel.

2.3.7.4 Each tray is to be fitted with a drain valve to enable rain water to be drained over the ship's side.

The drain valve and its pipes are to be made of low temperature material and to be thermally insulated from the ship’s hull.

2.3.7.5 Each tray is to have a sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled.

2.3.7.6 In addition to 2.3.7.2 to 2.3.7.5 of this Section, the drip trays at the bunkering connections, fixed or portable, are to be provided with a overflow hole near the top of its side wall through which LNG will be drained over the ship side by a pipe that preferably leads down near the water.

2.3.7.7 A water supply system providing a low-pressure water curtain is to be fitted to provide for additional protection of the hull steel and the ship side structure surrounding the drain pipe of drip tray. The system is to be capable of continuing to operate during bunkering operation.

2.3.8 Arrangement of entrances and other openings in enclosed spaces

2.3.8.1 Direct access is not to be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 2.3.9 is to be provided.

2.3.8.2 If the fuel preparation room is approved located below deck, the room is, as far as practicable, to have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 2.3.9 of this Section is to be provided.

2.3.8.3 Unless access to the tank connection space is independent and direct from open deck, it is to be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.

2.3.8.4 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances is to be arranged with an airlock which complies with 2.3.9.

2.3.8.5 For inerted spaces, access arrangements are to be such that unintended entry by personnel is prevented. If access to such spaces is not from an open deck, sealing arrangements are to ensure that leakages of inert gas to adjacent spaces are prevented.

2.3.9 Airlocks

2.3.9.1 An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of the International Convention on Load Lines, the door sill is not to be less than 300 mm in height. The doors are to be self-closing without any holding back arrangements.

2.3.9.2 Airlocks are to be mechanically ventilated at an overpressure[①] relative to the adjacent hazardous area or space.

2.3.9.3 The airlock is to be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events are to be evaluated in the risk analysis according to 1.1.6 of the Rules.

2.3.9.4 Airlocks are to have a simple geometrical form. They are to provide free and easy passage, and to have a deck area not less than 1.5 m^2. Airlocks are not to be used for other purposes, for instance as store rooms.

2.3.9.5 An audible and visual alarm system to give a warning on both sides of the airlock is to be provided to indicate if more than one door is moved from the closed position.

2.3.9.6 For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space, access to the space is to be restricted until the ventilation has been reinstated. Audible and visual alarms are to be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

2.3.9.7 Essential equipment required for safety is not to be de-energized and is to be of a certified safe type. This may include lighting, fire detection, gas detection, public address and general alarms systems.

① The minimum overpressure value may refer to IEC 60092-506 Electrical Installations in Ships – Special Features – Ships carrying specific dangerous goods and materials hazardous only in bulk.

CHAPTER 3 MATERIAL AND PIPE DESIGN

Section 1 GENERAL PROVISIONS

3.1.1 Goal

3.1.1.1 The goal of this Chapter is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

3.1.2 Functional requirements

3.1.2.1 This Chapter relates to functional requirements in 1.1.3.2 (1), (5), (6), (8), (9) and (10). In particular, the following apply:

(1) Fuel piping is to accommodate thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses;

(2) Provision is to be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure;

(3) If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid is to be fitted;

(4) Low temperature piping is to be thermally isolated from the adjacent hull structure to prevent the temperature of the hull from falling below the design temperature of the hull material.

Section 2 PIPE DESIGN

3.2.1 General requirements

3.2.1.1 This Section applies to the pipes of which the internal may contact with natural gas.

3.2.1.2 Fuel pipes and all other piping are to be colour marked[①] in accordance with a standard accepted by CCS.

3.2.1.3 Where tanks or piping are separated from hull structure by thermal isolation, provision is to be made for electrically bonding to the ship structure for both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded.

3.2.1.4 All pipelines which may be isolated in a liquid full condition are to be provided with relief valves.

3.2.1.5 Pipes, which may contain low temperature fuel, are to be thermally insulated to an extent which will minimize condensation of moisture or frosting.

3.2.1.6 Piping other than fuel supply piping and cabling may be arranged in the double wall piping or duct provided that they do not create a source of ignition or compromise the integrity of the double pipe or duct. The double wall piping or duct is to only contain piping or cabling necessary for operational purposes.

① E.g. GB 3033 Ship and marine technology - Identification colours for the content of piping systems - Part 2: Additional colours for different media and/or functions and EN ISO 14726 Ship and marine technology - Identification colours for the content of piping systems.

3.2.1.7 The valves and fittings in the piping are to be tested according to the relevant requirements of Chapter 13 of the Rules.

3.2.1.8 Metallic or non-metallic materials not covered in this Chapter, if used in the piping, are to be approved by CCS.

3.2.2 Wall thickness

3.2.2.1 The minimum wall thickness is to be calculated as follows:

$$t = \frac{t_0+b+c}{1-\frac{a}{100}} \text{ mm}$$

where:

t_0——theoretical thickness, in mm, $t_0 = \frac{PD}{2.0Ke+P}$;

with:

P——design pressure, in MPa, refer to in 3.2.3 of this Section;

D——outside diameter, in mm;

K——allowable stress, in N/mm², referred to in 3.2.4 of this Section; and

e——efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases, an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process;

b——allowance for bending, in mm. The value of b is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b is to be:

b

with: r——mean radius of the bend, in mm;

c——corrosion allowance, in mm. If corrosion or erosion is expected, the wall thickness of the piping is to be increased over that required by other design regulations. This allowance is to be consistent with the expected life of the piping; and

a——negative manufacturing tolerance for thickness, %.

3.2.2.2 In addition to the aforementioned, the minimum wall thickness is to be in accordance with CCS Rules.

3.2.3 Design conditions

3.2.3.1 The greater of the following design conditions is to be used for piping, piping system and components[①,②]:

(1) for systems or components which may be separated from their relief valves and which contain only vapour at all times, vapour pressure at 45°C assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature;

(2) the MARVS of the fuel tanks and fuel processing systems;

(3) the pressure setting of the associated pump or compressor discharge relief valve;

(4) the maximum total discharge or loading head of the fuel piping system; or

(5) the relief valve setting on a pipeline system.

3.2.3.2 Piping, piping systems and components are to have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa.

3.2.4 Allowable stress

3.2.4.1 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 3.2.2.1 of this Section is to be the lower of the following values:

$$\frac{R_m}{2.7} \text{ or } \frac{R_e}{1.8}$$

where:

R_m——specified minimum tensile strength at room temperature, in N/mm^2; and

R_e——specified minimum yield stress at room temperature, in N/mm^2. If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

3.2.4.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness is to be increased over that required by 3.2.2 of this Section. If this is impracticable or would cause excessive local stresses, these loads are to be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to supports, ship deflections, liquid pressure surge during transfer operation, the weight of suspended valves, reaction to loading arm connections, or otherwise.

3.2.4.3 For pipes made of materials other than steel, the allowable stress is to be agreed by CCS.

3.2.4.4 High pressure fuel piping systems are to have sufficient constructive strength. This is to be confirmed by carrying out stress analysis and taking into account:

(1) stresses due to the weight of the piping system;

(2) acceleration loads when significant; and

(3) internal pressure and loads induced by hog and sag of the ship.

3.2.4.5 When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship, is to be carried out for each branch of the piping system.

3.2.4.6 The stress of low temperature pipes is to be analyzed in accordance with CCS Guidelines for Stress Analysis of Low Temperature Pipe.

---

① Lower values of ambient temperature regarding design condition in 3.2.3.1(1) may be accepted by CCS for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

② For ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank. Reference is made to the Application of amendments to gas carrier codes concerning type C tank loading limits (SIGTTO/IACS).

3.2.5 Flexibility of piping

3.2.5.1 The arrangement and installation of fuel piping are to provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account.

3.2.6 Piping fabrication and joining details

3.2.6.1 Flanges, valves and other fittings are to comply with a standard acceptable to CCS, taking into account the design pressure defined in 3.2.3.1 of this Section. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 3.2.3.1 may be accepted.

3.2.6.2 All valves and expansion joints used in high pressure fuel piping systems are to be approved according to a standard acceptable to CCS.

3.2.6.3 The piping system is to be joined by welding with a minimum of flange connections. Gaskets are to be protected against blow-out.

3.2.6.4 Piping fabrication and joining details are to comply with the following:

(1) Direct connections

a) Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings are to be removed;

b) Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, are only to be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than minus 55°C;

c) Screwed couplings complying with recognized standards are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

(2) Flanged connections

① Flanges in flange connections are to be of the welded neck, slip-on or socket welded type; and

② For all piping except open ended, the following restrictions apply:

a) For design temperatures colder than minus 55°C, only welded neck flanges are to be used; and

b) For design temperatures colder than minus 10°C, slip-on flanges are not to be used in nominal sizes above 100 mm and socket welded flanges are not to be used in nominal sizes above 50 mm.

(3) Expansion joints

Where bellows and expansion joints are provided in accordance with 3.2.6.1 of this Section, the following are to apply:

① If necessary, bellows are to be protected against icing;

② Slip joints are not to be used except within the liquefied gas fuel storage tanks; and

③ Bellows are normally not to be arranged in enclosed spaces.

(4) Other connections

Piping connections are to be joined in accordance with 3.2.6.4 (1) to 3.2.6.4 (3) of this Section, but for other exceptional cases, CCS may consider alternative arrangements.

3.2.6.5 Expansion joints are to avoid excessive expansion and compression, and the adjacent pipes are to be suitably supported and fixed. Bellow expansion joints are to be protected against mechanical damage. Flange connections are to be fitted with means against loosening of the nuts, such as lock washers.

3.2.6.6 Sliding expansion joints are not to be used in the gas supply piping.

Section 3 MATERIALS

3.3.1 Metallic materials

3.3.1.1 Materials for fuel containment and piping systems are to comply with the minimum requirements given in the following tables:

Table 3.3.1.1 (1): Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 3.3.1.1(2): Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to minus 55°C.

Table 3.3.1.1(3): Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below minus 55°C and down to minus 165°C.

Table 3.3.1.1(4): Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to minus 165°C.

Table 3.3.1.1 (5): Plates and sections for hull structures required by 4.2.11.1 (2).

Table 3.3.1.1 (1)

PLATES, PIPES (SEAMLESS AND WELDED) [1,2], SECTIONS AND FORGINGS FOR FUEL TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0℃	
CHEMICAL COMPOSITION AND HEAT TREATMENT	
◆ Carbon-manganese steel	
◆ Fully killed fine grain steel	
◆ Small additions of alloying elements by agreement with CCS	
◆ Composition limits to be approved by CCS	
◆ Normalized, or quenched and tempered[4]	
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS	
Sampling frequency	
◆ Plates	Each ‘piece’ to be tested
◆ Sections and forgings	Each ‘batch’ to be tested
Mechanical properties	
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [5]
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27 J

◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41 J	
◆ Test temperature	Thickness t (mm)	Test temperature (°C)
	$t \leq 20$	0
	$20 < t \leq 40^3$	-20

Notes:
1.For seamless pipes and fittings, normal practice applies. The use of longitudinally and spirally welded pipes is to be specially approved by CCS (See Note ①).
2.Charpy V-notch impact tests are not required for pipes.
3. This Table is generally applicable to material thicknesses up to 40 mm. Charpy V-notch impact tests are to comply with Note ② in this Table for material thickness greater than 40 mm and up to 50 mm. Proposals for greater thicknesses are to be approved by CCS.
4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.
5.Materials with specified minimum yield stress exceeding 410 N/mm² may be approved by CCS. For these materials, particular attention is to be given to the hardness of the welded and heat affected zones.

Notes: ① For welded pressure pipes and materials for fuel tanks and process pressure vessels, the chemical compositions and mechanical properties are to comply with Chapter 3 and Chapter 4, PART ONE of CCS Rules for Materials and Welding.

② For material thickness of more than 40mm and up to 50 mm, Charpy V-notch tests are to be conducted as follows:

Toughness (Charpy V-notch test)		
Test temperature	Thickness t (mm)	Test temperature (°C)
	$40 < t \leq 50^1$	-20^2
	$40 < t \leq 50^1$	-30^3

Notes:
1. In addition to rolled steel specified in Section 2 and Section 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding, the products of more than 40 mm in thickness are to be subject to a set of impact tests at the center of thickness.
2. Type C tanks and process pressure vessels. In addition, a post-weld stress relief heat treatment is to be carried out. An alternative to this heat treatment, for instances, an engineering critical assessment, is to be approved by CCS or subject to recognized standards.
3. Fuel tanks other than type C tanks.

Table 3.3.1.1 (2)

PLATES, SECTIONS AND FORGINGS[1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0℃ AND DOWN TO MINUS 55℃ Maximum thickness 25 mm[2]				
CHEMICAL COMPOSITION AND HEAT TREATMENT				
◆ Carbon-manganese steel				
◆ Fully killed, aluminium treated fine grain steel				
◆ Chemical composition (ladle analysis)				
C	Mn	Si	S	P
≤ 0.16%[3]	0.7% ~ 1.60%	0.1% ~ 0.50%	≤ 0.025%	≤ 0.025%
Optional additions: alloy and grain refining elements may be generally in accordance with the following:				

Ni	Cr	Mo	Cu	Nb	V
≤ 0.8%	≤ 0.25%	≤ 0.08%	≤ 0.35%	≤ 0.05%	≤ 0.1%
Al content total 0.020% min. (Acid soluble 0.015% min.)					
◆ Normalized, or quenched and tempered[4]					

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS	
Sampling frequency	
◆ Plates	Each ‘piece’ to be tested
◆ Sections and forgings	Each ‘batch’to be tested
Mechanical properties	
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [5]
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27 J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41 J
◆ Test temperature	5℃ below the design temperature or -20℃, whichever is lower

Notes:

1. The Charpy V-notch and chemistry requirements for forgings may be specially considered by CCS.

2. For material thickness of more than 25 mm, Charpy V-notch tests are to be conducted as follows:

Material thickness (mm)	Test temperature (℃)
25 < t ≤30	10℃ below the design temperature or -20℃, whichever is lower
30 < t ≤35	15℃ below the design temperature or -20℃, whichever is lower
35 < t ≤40	20℃ below design temperature
40 < t	Temperature approved by CCS (See Note ①)

The impact energy value is to be in accordance with the table for the applicable type of test specimen.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5℃ below design temperature or -20℃, whichever is lower.

For thermally stress relieved reinforcements and other fittings, the test temperature is to be the same as that required for the adjacent tank-shell thickness.

3. By special agreement with CCS, the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40℃.

4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by CCS. For these materials, particular attention is to be given to the hardness of the welded and heat affected zones. For materials exceeding 25 mm in thickness for which the test temperature is -60℃ or lower, the application of specially treated steel or steel in accordance with Table 3.3.1.1 (3) of this Chapter may be necessary.

Note: ① For material thickness of more than 40mm and up to 50 mm, Charpy V-notch tests are to be conducted as follows:

Toughness (Charpy V-notch test)		
Test temperature	Thickness *t* (mm)	Test temperature (℃)
	40 < t ≤ 50[1]	5℃ below the design temperature or -20℃, whichever is lower[2]
	40 < t ≤ 45[1]	25℃ below design temperature[3]
	45 < t ≤ 50[1]	30℃ below design temperature[3]

Notes:

1. In addition to rolled steel specified in Section 2 and Section 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding, the products of more than 40 mm in thickness are to be subject to a set of impact tests at the center of thickness.
2. Type C tanks and process pressure vessels. A post-weld stress relief heat treatment is to be carried out for design temperatures below 0℃ and down to minus 10℃. A post-weld heat treatment is to be carried out for design temperatures below minus 10℃ and down to minus 55℃. An alternative to these heat treatment, for instances an engineering critical assessment, is to be approved by CCS or subject to recognized standards.
3. Fuel tanks other than type C tanks.

Table 3.3.1.1 (3)

PLATES, SECTIONS AND FORGINGS[1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW MINUS 55℃ AND DOWN TO MINUS 165℃[2] Maximum thickness 25 mm[3,4]		
Minimum design temp. (℃)	Chemical composition[5] and heat treatment	Impact test temp. (℃)
-60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6]	-65
-65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6,7]	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6,7]	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered[6,7,8]	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered[6]	-196
-165	Austenitic steel, such as types 304, 304L, 316, 316L, 321 and 347, solution treated[9]	-196
-165	Austenitic manganese steel - hot rolled and cooling controlled [10 and 11]	-196
-165	Aluminium alloy, such as type 5083, annealed	Not required
-165	Austenitic Fe-Ni alloy (36% nickel). Heat treatment as agreed	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS	
Sampling frequency	
◆ Plates	Each ‘piece’ to be tested
◆ Sections and forgings	Each ‘batch’ to be tested
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J

Notes:

1. The impact test required for forgings used in critical applications is to be subject to special consideration by CCS.
2. The requirements for design temperatures below –165℃ are to be specially agreed with CCS.
3. For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests are to be conducted as follows:

Material thickness (mm)	Test temperature (℃)
$25 < t \leq 30$	10℃ below design temperature
$30 < t \leq 35$	15℃ below design temperature
$35 < t \leq 40$	20℃ below design temperature

The energy value is to be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values are to be specially considered (see Note ①).

4. For 9% Ni steel, austenitic stainless steel, austenitic manganese steel and aluminium alloy, thickness greater than 25 mm may be used. 5. The composition limits are to be in accordance with recognized standards. 6. TMCP nickel steel are to be subject to acceptance by CCS. 7. A lower minimum design temperature for quenched and tempered steel may be specially agreed with CCS. 8. A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to –165℃, provided that the impact tests are carried out at –196℃. 9. The impact test may be omitted subject to agreement with CCS. 10. The use of materials in the ships constructed on or after 1 January 2026 is to comply with the Revised Guidelines on the Application of High Manganese Austenitic Steel for Cryogenic Service (MSC.1/CIRC.1599/REV.1) or CCS Guidelines on the Application of Low Temperature High Manganese Austenite Steel. 11. The impact test is not to be omitted for high manganese austenitic steel.

Note: For material thickness of more than 40mm and up to 50 mm, Charpy V-notch tests are to be conducted as follows:

Toughness (Charpy V-notch test)	
Thickness t (mm)	Test temperature (℃)
$40 < t \leq 45$[1]	25℃ below design temperature
$45 < t \leq 50$[1]	30℃ below design temperature
Notes: 1. In addition to rolled steel specified in Section 2 and Section 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding, the products of more than 40 mm in thickness are to be subject to a set of impact tests at the center of thickness.	

Table 3.3.1.1 (4)

PIPES (SEAMLESS AND WELDED)[1], FORGINGS[2] AND CASTINGS[2] FOR FUEL AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0℃ AND DOWN TO MINUS 165℃[3] Maximum thickness 25 mm			
Minimum design temp.(℃)	Chemical composition[5] and heat treatment	Impact test	
		Test temperature (℃)	Minimum average energy (KV)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed[6]	See note 4	27
-65	2.25% nickel steel. Normalized, normalized and tempered or quenched and tempered[6]	-70	34
-90	3.5% nickel steel. Normalized, normalized and tempered or quenched and tempered[6]	-95	34
-165	9% nickel steel[7]. Double normalized and tempered or quenched and tempered	-196	41
	Austenitic steel, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated[8]	-196	41
	Aluminium alloy; such as type 5083 annealed		Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS
Sampling frequency
◆ Each 'batch' to be tested.
Toughness (Charpy V-notch test)
◆ Impact test: Longitudinal test pieces
Notes: 1. The use of longitudinally or spirally welded pipes is to be specially approved by CCS. 2. The requirements for forgings and castings may be subject to special consideration by CCS. 3. The requirements for design temperatures below -165℃ are to be specially agreed with CCS. 4. The test temperature is to be 5℃ below the design temperature or -20℃, whichever is lower. 5. The composition limits are to be in accordance with recognized standards. 6. A lower design temperature may be specially agreed with CCS for quenched and tempered materials. 7. This chemical composition is not suitable for castings. 8. The impact test may be omitted subject to agreement with CCS.

Table 3.3.1.1 (5)

PLATES AND SECTIONS FOR HULL STRUCTURE REQUIRED BY 4.2.11.1 (2)								
Minimum design temperature of hull structure (℃)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above	Recognized standards							
down to -5	15	25	30	50	25	45	50	50
down to -10	×	20	25	50	20	40	50	50
down to -20	×	×	20	50	×	30	50	50
down to -30	×	×	×	40	×	20	40	50
Below -30	In accordance with Table 3.3.1.1 (2), except that the thickness limitation given in Table 3.3.1.1 (2) and in footnote 2 of that table does not apply							
Notes: 'x' means steel grade not to be used.								

3.3.1.2 Materials having a melting point below 925℃ are not to be used for piping outside the fuel tanks.

3.3.1.3 For CNG tanks, the use of materials not covered above may be specially considered by CCS.

3.3.1.4 The outer pipe or duct containing high pressure gas in the inner pipe is as a minimum to fulfill the material requirements for pipe materials with design temperature down to minus 55℃ in Table 3.3.1.1.(4).

3.3.1.5 The outer pipe or duct around liquefied gas fuel pipes is as a minimum to fulfill the material requirements for pipe materials with design temperature down to minus 165℃ in Table 3.3.1.1 (4).

3.3.1.6 Castings and forgings for fuel pipes and process pipes for design temperatures above 0℃ are to comply with the relevant requirements of Chapter 5 and Chapter 6, PART ONE of CCS Rules for Materials and Welding.

3.3.1.7 The materials having chemical compositions or mechanical properties distinct from those required in 3.3.1.1 of this Section may be accepted by signing a special agreement with CCS.

3.3.1.8 The steel for hull structures is to comply with the requirements for steel grades of Chapter 3, PART ONE of CCS Rules for Materials and Welding.

3.3.2 Non-metallic materials

3.3.2.1 The selection and use of non-metallic materials may refer to the relevant requirements of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and PART TWO of CCS Rules for Materials and Welding.

CHAPTER 4 FUEL CONTAINMENT SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 Goal

4.1.1.1 The goal of this Chapter is to ensure that gas storage is adequate so as to minimize the risk to personnel, ship and environment to a level that is equivalent to that to a conventional oil fuelled ship.

4.1.2 Functional requirements

4.1.2.1 This Chapter relates to functional requirements in 1.1.3.2 (1), (2), (5) and (8) to (17)) of the Rules. In particular, the following apply:

(1) The fuel containment system is to be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

① exposure of ship materials to temperatures below acceptable limits;

② flammable fuels spreading to locations with ignition sources;

③ toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

④ restriction of access to muster stations, escape routes and life-saving appliances (LSA); and

⑤ reduction in availability of LSA.

(2) The pressure and temperature in the fuel tank are to be kept within the design limits of the containment system and possible carriage requirements of the fuel;

(3) The fuel containment arrangement is to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

(4) If portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanently installed tanks as described in this Chapter.

4.1.3 General requirements

4.1.3.1 The MARVS of liquefied gas fuel tank is not to exceed 1.0 MPa for sea-going ships;

And not to exceed 1.2 MPa for inland waterways ships.

4.1.3.2 The Maximum Allowable Working Pressure (MAWP) of the gas fuel tank is not to exceed 90% of the MARVS.

4.1.3.3 A fuel containment system located below deck is to be gastight towards adjacent spaces.

4.1.3.4 All tank connections, fittings, flanges and valves are to be enclosed in gastight tank connection spaces, unless the tank connections are on open deck. The space is to be able to safely contain leakage from the tank in case of leakage from the tank connections.

4.1.3.5 If liquefied gas fuel tanks are located on open deck, the ship steel is to be protected from potential leakages from tank connections and other sources of leakage by use of drip trays. The material is to have a design temperature corresponding to the temperature of the fuel carried at atmospheric pressure. The normal operation pressure of the tanks is to be taken into consideration for protecting the steel structure of the ship.

Whether a drip tray is needed or not is to depend on:

(1) Where the tank is located on open deck, drip trays are to be provided to protect the deck from

leakages from tank connections and other sources of leakage;

（2）Where the tank connections are located on open deck with the tank located below open deck, drip trays are to be provided to protect the deck from leakages from tank connections and other sources of leakage;

（3）Where both the tank and the tank connections are located below the deck, all tank connections are to be located in a tank connection space. In such case, drip trays are not required.

4.1.3.6 In addition, the fitting of tank connection space is to be in accordance with the following:

（1）A tank connection space may be applied to tanks located on open deck. A tank connection space may be applied to ships that it is vital to the ship safety to restrict hazardous zones, or for giving environmental protection for essential safety equipment associated to gas supply systems.

（2）For tanks located in a semi-enclosed space, a tank connection space is to be fitted in general. If not, and the semi-enclosed space contains connections, valves or other equipment with potential leakage, the structures surrounding the space is to be made of low temperature materials, and at least 2 gas detectors are to be provided and the monitoring requirements for tank connection spaces of Chapter 12 of the Rules are to be met. A drip tray is to be fitted below the position where a LNG leakage may occur.

（3）A tank on an open deck, if provided with a tank connection space, may not comply with 4.1.3.5 of the Rules.

4.1.3.7 Pipe connections to the fuel storage tank are to be mounted above the highest liquid level in the tanks, except for fuel storage tanks of type C. Connections below the highest liquid level may however also be accepted for other tank types after special consideration by CCS.

4.1.3.8 Piping between the type C tank and its first stop valve connected is to have equivalent safety as the type C tank, and protected according to 4.1.3.13 or 4.1.3.14 of this Section.

4.1.3.9 The material of the bulkheads or boundaries of the tank connection space is to have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario.

4.1.3.10 The tank connection space is to be designed to withstand the maximum pressure buildup during such a leakage defined in 4.1.3.9. Alternatively, pressure relief venting to a safe location (mast) can be provided.

4.1.3.11 Where a tank connection space is provided with a mechanical ventilation system of the extraction type required in 10.2.1 of the Rules with a maximum potential evaporation not exceeding the ventilation volume, the built-up pressure mentioned in 4.1.3.10 of this Section may not be taken into consideration, but the maximum hydrostatic head caused by leakage from the tank and effective supporting to inner equipment are to be considered.

4.1.3.12 The probable maximum amount of leakage into the tank connection space is to be determined based on detail design, detection and shutdown systems.

4.1.3.13 If piping is connected below the liquid level of the tank, it has to be protected by a secondary barrier up to the first valve.

4.1.3.14 Secondary barriers may not be required where the pipes mentioned in 4.1.3.10 of this Section are located in the tank connection space.

4.1.3.15 Means are to be provided whereby liquefied gas in the storage tanks can be safely emptied.

4.1.3.16 It is to be possible to empty, purge and vent fuel storage tanks with fuel piping systems. Instructions for carrying out these procedures are to be available on board. Inerting is to be performed with an inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipes.

Section 2 LNG FUEL CONTAINMENT SYSTEMS

4.2.1 General requirements

4.2.1.1 The risk assessment required in 1.1.6 of the Rules is to include evaluation of the ship's LNG fuel containment system, and may lead to additional safety measures for integration into the overall vessel design.

4.2.1.2 The design life of fixed fuel containment system is not to be less than the design life of the ship or 20 years, whichever is greater.

4.2.1.3 The design life of portable tanks is not to be less than 20 years.

4.2.1.4 The design of fuel containment system is to be suitable for its expected navigational circumstances.

4.2.1.5 Liquefied gas fuel containment systems are to be designed with suitable safety margins:

(1) to withstand, in the intact condition, the environmental conditions anticipated for the design life of liquefied gas fuel containment system and the loading conditions appropriate for them, which are to include full homogeneous and partial load conditions and partial filling to any intermediate levels; and

(2) being appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, aging and construction tolerances.

4.2.1.6 The structural strength of liquefied gas fuel containment system is to be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue.The specific design conditions that are to be considered for the design of each liquefied gas fuel containment system are given in 4.2.13 to 4.2.16 of this Section. There are three main categories of design conditions:

(1) Ultimate Design Conditions – The liquefied gas fuel containment system structure and its structural components are to withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design is to take into account proper combinations of the following loads:

① internal pressure;

② external pressure;

③ dynamic loads due to the motion of the ship in all loading conditions;

④ thermal loads;

⑤ sloshing loads;

⑥ loads corresponding to ship deflections;

⑦ tank and liquefied gas fuel weight with the corresponding reaction in way of supports;

⑧ insulation weight;

⑨ loads in way of towers and other attachments; and

⑩ test loads.

(2) Fatigue Design Conditions – The liquefied gas fuel containment system structure and its structural components are not to fail under accumulated cyclic loading.

(3) Accidental Design Conditions – The liquefied gas fuel containment system is to meet each of the following accidental design conditions (accidental or abnormal events), addressed in this Code:

① Collision – The liquefied gas fuel containment system is to withstand the collision loads specified in 4.2.7.5 (1) of this Section without deformation of the supports or the tank structure in way of the supports likely to endanger the tank and its supporting structure.

② Fire – The liquefied gas fuel containment systems are to sustain without rupture the rise in internal pressure specified in 4.5.3.1 of this Chapter under the fire scenarios envisaged therein.

③ Flooded compartment causing buoyancy on tank – the anti-flotation arrangements are to sustain the upward force, specified in 4.2.7.5 (2) of this Section and there is to be no endangering plastic deformation to the hull. Plastic deformation may occur in the fuel containment system, provided it does not endanger the safe evacuation of the ship.

4.2.1.7 Measures are to be applied to ensure that scantlings required meet the structural strength provisions and are maintained throughout the design life. Measures may include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting.

4.2.1.8 An inspection/survey plan for the fuel containment system is to be developed and approved by CCS. The inspection/survey plan is to identify aspects to be examined and/or validated during surveys throughout the life of liquefied gas fuel containment system and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting liquefied gas fuel containment system design parameters. The inspection/survey plan may include specific critical locations as per 4.2.10.2 (13) or 4.2.10.2 (14) of this Section.

4.2.1.9 Liquefied gas fuel containment systems are to be designed, constructed and equipped to provide adequate means of access to areas that need inspections as specified in the inspection/survey plan. Liquefied gas fuel containment systems, including all associated internal equipment, are to be designed and built to ensure safety during operation, inspections and maintenance.

4.2.2 LNG fuel containment safety principles

4.2.2.1 The containment systems are to be provided with a complete secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.

4.2.2.2 The size and configuration or arrangement of the secondary barrier may be reduced or omitted where an equivalent level of safety can be demonstrated in accordance with 4.2.2.3 to 4.2.2.6 of this Section as applicable.

4.2.2.3 Fuel containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low but where the possibility of leakages through the primary barrier cannot be excluded, are to be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages (a critical state means that the crack develops into unstable condition), and are to comply with the following requirements:

(1) Failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) are to have a sufficiently long development time for remedial actions to be taken; and

(2) Failure developments that cannot be safely detected before reaching a critical state are to have a predicted development time that is much longer than the expected lifetime of the tank.

4.2.2.4 No secondary barrier is required for liquefied gas fuel containment systems, e.g. type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.

4.2.2.5 In addition, vacuum insulated type C independent tanks are to comply with the following requirements:

(1) The outer shell is to be made of low temperature materials and have a design temperature not greater than that of the inner shell.

(2) Where the tank is located on open deck or in a semi-enclosed space, all openings of the inner shell

are to be located above the potential highest liquid level, and the provisions of (1) above need not be applied for the outer shell.

4.2.2.6 For independent tanks requiring full or partial secondary barrier, means for safely disposing of leakages from the tank is to be arranged.

4.2.3 Design of secondary barriers

4.2.3.1 Secondary barriers are to be provided in accordance with the following table:

Table 4.2.3.1

Basic tank type	Secondary barrier requirements
Membrane	Complete secondary barrier
Independent	
Type A	Complete secondary barrier
Type B	Partial secondary barriers
Type C	No secondary barrier required

4.2.3.2 The design of secondary barriers, including spray shield if fitted, is to be such that:

(1) It is capable of containing any envisaged leakage of liquefied gas fuel for a period of 15 days unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 4.2.10.2 (10) of this Section;

(2) Physical, mechanical or operational events within the liquefied gas fuel tank that could cause failure of the primary barrier are not to impair the due function of the secondary barrier, or vice versa;

(3) Failure of a support or an attachment to the hull structure is not to lead to loss of liquid tightness of both the primary and secondary barriers;

(4) It is capable of being periodically checked for its effectiveness by means of a visual inspection or other suitable means acceptable to CCS;

(5) The methods required in 4.2.3.2 (4) are to be approved by CCS and are to include, as a minimum:

① details on the size of defect acceptable and the location within the secondary barrier, before its liquid tight effectiveness is compromised;

② accuracy and range of values of the proposed method for detecting defects in ① above;

③ scaling factors to be used in determining the acceptance criteria if full-scale model testing is not undertaken; and

④ effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test.

(6) In sea-going ships, the secondary barrier is to fulfill its functional requirements at a static angle of heel of 30°, and in inland waterways ships, the corresponding static angle of heel is 20°.

4.2.3.3 Partial secondary barriers are to be used with a small leak protection system and meet the provisions in 4.2.3.2 of this Section. The small leak protection system is to include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquefied gas fuel down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

4.2.3.4 The capacity of the partial secondary barrier is to be determined, based on the liquefied gas fuel leakage corresponding to the extent of failure resulting from the crack propagation analysis, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors, referring to 4.2.10.2 (7) of this Section.

4.2.3.5 The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.

4.2.3.6 For independent tanks for which the geometry does not present obvious locations for leakage to collect, the partial secondary barrier is also to fulfill its functional requirements at a nominal static angle of trim.

4.2.4 Supporting arrangements

4.2.4.1 The liquefied gas fuel tanks are to be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 4.2.7.2 to 4.2.7.5 of this Section, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

4.2.4.2 Anti-flotation arrangements are to be provided for independent tanks and capable of withstanding the loads defined in 4.2.7.5 (2) without plastic deformation likely to endanger the hull structure.

4.2.4.3 Supports and supporting units are to withstand the loads defined in 4.2.7.3 (3) ⑧ and 4.2.7.5, but these loads need not be combined with each other or with wave-induced loads.

4.2.4.4 For vacuum insulated type C independent tanks where the shell is made of low temperature material, the tank saddle is also to be made of low temperature material with a design temperature at least same to the shell, and its connection to the hull base is to be thermally insulated.

4.2.5 Associated structure and equipment

4.2.5.1 Fuel containment systems are to be designed for the loads imposed by associated structure and equipment. This includes pump towers, liquefied gas fuel domes, liquefied gas fuel pumps and piping, stripping pumps and piping, nitrogen piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles and instrumentation systems (such as pressure, temperature and strain gauges).

4.2.6 Thermal insulation

4.2.6.1 Thermal insulation is to be provided as required to protect the hull from temperatures below those allowable and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Section 7 of this Chapter.

4.2.7 Design loads

4.2.7.1 General requirements

(1) This Section defines the design loads that are to be considered with regard to the requirements in 4.2.8 to 4.2.10. This includes load categories (permanent, functional, environmental and accidental) and the description of the loads.

(2) The extent to which these loads are to be considered depends on the type of tank, and is detailed in the following paragraphs.

(3) Tanks, together with their supporting structure and other fixtures, are to be designed taking into account relevant combinations of the loads described below.

4.2.7.2 Permanent loads

(1) Gravity loads

The weight of tank and thermal insulation as well as loads caused by towers and other attachments are to be considered.

(2) Permanent external loads

Gravity loads of structures and equipment acting externally on the tank are to be considered.

4.2.7.3 Functional loads

(1) Loads arising from the operational use of the tank system are to be classified as functional loads.

(2) All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, are to be considered.

(3) As a minimum, the effects from the following criteria, as applicable, are to be considered when establishing functional loads:

① internal pressure;

② external pressure;

③ thermally induced loads;

④ vibration;

⑤ interaction loads;

⑥ loads associated with construction and installation;

⑦ test loads;

⑧ static heel loads;

⑨ weight of liquefied gas fuel;

⑩ sloshing;

⑪ wind impact, wave impacts and green sea effect for tanks installed on open deck.

(4) Internal pressure

① In all cases, including 4.2.7.3 (4)② of this Section, P_0 is not to be less than MARVS.

② For liquefied gas fuel tanks where there is no temperature control and where the pressure of the liquefied gas fuel is dictated only by the ambient temperature, P_0 is not to be less than the gauge vapour pressure of the liquefied gas fuel at a temperature of 45℃, except as follows:

(a) Lower values of ambient temperature may be accepted by CCS for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required;

(b) For ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank.

③ Subject to special consideration by CCS and to the limitations given in 4.2.13 to 4.2.16 of this Section for the various tank types, a vapour pressure P_h higher than P_0 may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.

④ Pressure used for determining the internal pressure is to be:

(a) $(P_{gd})_{\max}$ is the associated liquid pressure determined using the maximum design accelerations;

(b) $(P_{gd\,site})_{\max}$ is the associated liquid pressure determined using site specific accelerations;

(c) P_{eq} is to be the greater of P_{eq1} and P_{eq2} calculated as follows:

$$P_{eq1} = P_o + (P_{gd})_{\max} \text{ MPa}$$

$$P_{eq2} = P_h + (P_{gdsite})_{max} \text{ MPa}$$

⑤ The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the liquefied gas fuel due to the motions of the ship referred to in 4.2.7.4 (1) of this Section. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations is to be calculated as follows:

$$P_{gd} = \alpha_\beta Z_\beta \frac{\rho}{1.02 \times 10^5} \text{ MPa}$$

where:

a_β——dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β, see Figure 4.2.7.3 (4).

For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, is to be used.

Z_β——largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the direction β, see Figure 4.2.7.3 (4)(b).

Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t\left(\frac{100 - FL}{FL}\right)$$

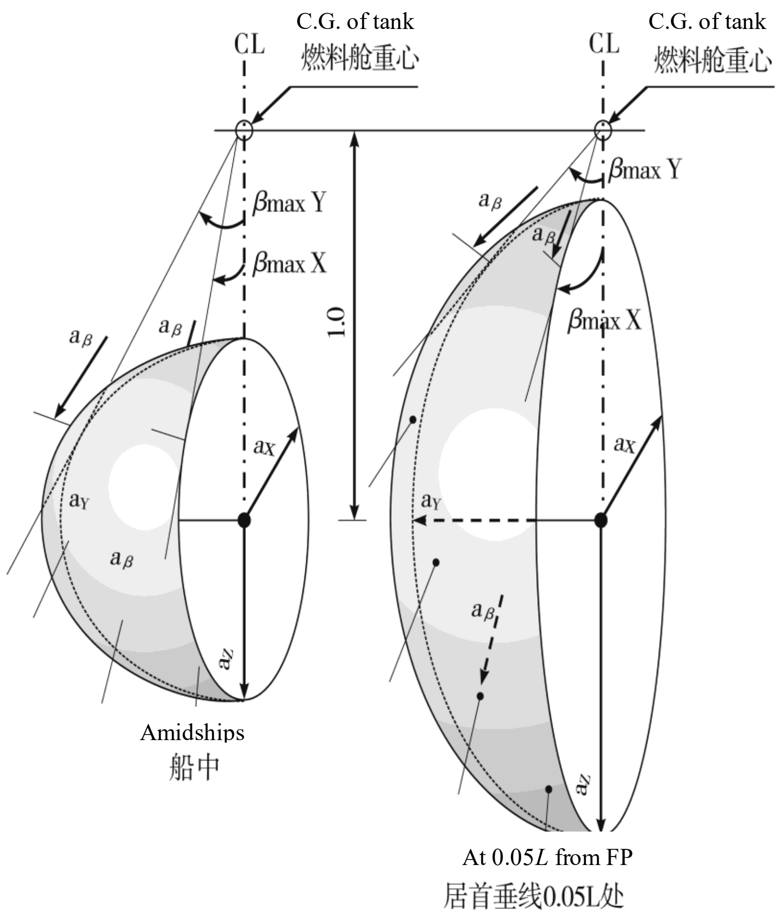
where:

V_t——tank volume without any domes; and

FL——filling limit according to Section 6 of this Chapter.

ρ——maximum liquefied gas fuel density at the design temperature, in kg/m^3。

The direction that gives the maximum value $(P_{gd})_{\max}$ or $(P_{gd\ site})_{\max}$ is to be considered. Where acceleration components in three directions need to be considered an ellipsoid is to be used instead of the ellipse in Figure 4.2.7.3 (4) (a). The above formula applies only to full tanks.



a_β= resulting acceleration (static and dynamic) in arbitrary direction β

a_x = longitudinal component of acceleration

a_y= transverse component of acceleration

a_z= vertical component of acceleration

Figure 4.2.7.3 (4) (a) – Acceleration ellipsoid

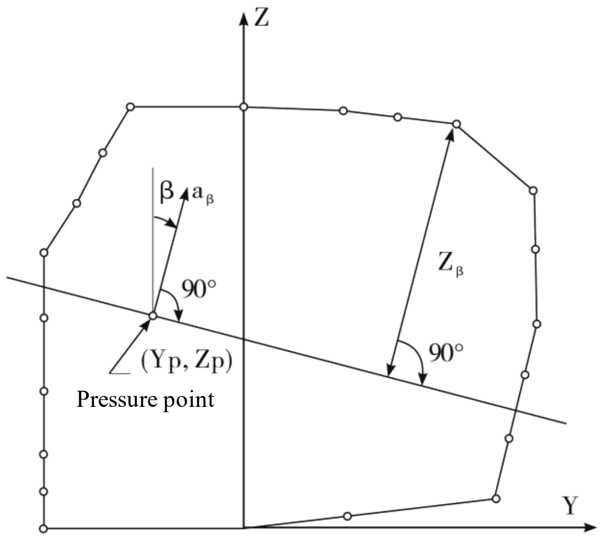


Figure 4.2.7.3 (4) (b) – Determination of internal pressure heads

(5) External pressure

External design pressure loads are to be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

(6) Thermally induced loads

① Transient thermally induced loads during cooling down periods are to be considered.

② Stationary thermally induced loads are to be considered for fuel containment systems where the design supporting arrangements or attachments at operating temperature may give rise to significant thermal stresses (the ambient temperature to be considered refers to 4.7.2 of this Section).

(7) Vibration

The potentially damaging effects of vibration on the fuel containment system are to be considered.

(8) Interaction loads

The static component of loads resulting from interaction between fuel containment system and the hull structure, as well as loads from associated structure and equipment, is to be considered.

(9) Loads associated with construction and installation

Loads or conditions associated with construction and installation are to be considered, e.g.lifting.

(10) Test loads

Account is to be taken of the loads corresponding to the testing of the fuel containment system referred to in Section 5, Chapter 13 of the Rules.

(11) Static heel loads

For sea-going ships, loads corresponding to the most unfavourable static heel angle within the range 0° to 30° are to be considered;

For inland waterways ships, loads corresponding to the most unfavourable static heel angle within the range 0° to 20°are to be considered.

(12) Other loads

Any other loads not specifically addressed, which could have an effect on the fuel containment system, are to be taken into account.

4.2.7.4 Environmental loads

(1) Loads due to ship motion

① The determination of dynamic loads is to take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading. The ship motion is to include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks are to be estimated at their centre of gravity and include the following components:

(a) vertical acceleration: motion accelerations of heave, pitch and roll (normal to the ship base);

(b) transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and

(c) longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

② Methods to predict accelerations due to ship motion are to be approved by CCS.

③ For sea-going ships with a length of greater than 50 m, the values of acceleration components in all directions may be calculated according to 4.28.2, Chapter 4, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For sea-going ships with a length of 50 m or below, such values may be calculated according to 1.5.2, Chapter 1, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

④ For inland waterways ships, the minimum component of acceleration due to the ship motion is to be determined by one of the following methods:

Method 1:

(a) longitudinal acceleration a_x: as specified in 4.2.7.5 (1) of this Chapter;

(b) transverse acceleration a_y: complying with the requirements for transverse acceleration of container in the securing calculation in CCS Rules for the Construction of Inland Waterways Steel Ships;

(c) vertical acceleration a_z: complying with the requirements for vertical acceleration of container in the securing calculation (including gravity effect) in CCS Rules for the Construction of Inland Waterways Steel Ships.

Method 2:

(a) longitudinal acceleration: 2g;

(b) transversal acceleration: 1g;

(c) straight upward acceleration: 1g;

(d) straight downward acceleration: 2g, considering the gravity effect.

⑤ Ships for restricted service may be given special consideration to accelerations due to the ship motion by CCS.

(2) Dynamic interaction loads

Account is to be taken of the dynamic component of loads resulting from interaction between fuel containment systems and the hull structure, including loads from associated structures and equipment.

(3) Sloshing loads

The sloshing loads on a fuel containment system and internal components are to be evaluated for the full range of intended filling levels.

Fuel tanks may be provided with a swashplate or swash bulkhead to reduce the impact from sloshing loads. For ships engaged on domestic voyages, evaluation of sloshing load may not be required, provided that the volume of an individual fuel tank is limited to not more than 5 m^3 or is above 5 m^3 but not more than 100 m^3 as well as with a swashplate or swash bulkhead under the standards① accepted by CCS.

(4) Snow and ice loads

Snow and icing is to be considered, if relevant.

(5) Loads due to navigation in ice

Loads due to navigation in ice are to be considered for ships intended for such service.

(6) Green sea loading

Account is to be taken to loads due to water on deck.

(7) Wind loads

Account is to be taken to wind generated loads as relevant.

4.2.7.5 Accidental loads

(1) Collision loads

The collision load is to be determined based on the fuel containment system under fully loaded condition with an inertial force corresponding to 'a' in the table below in forward direction and 'a/2' in the aft direction, where 'g' is gravitational acceleration.

Design Acceleration **Table 4.2.7.5**

Ship length (L)	Design acceleration (a)
$L > 100$m	$0.5g$
$60 < L \leq 100$m	$\left(2-\frac{3(L-60)}{80}\right)g$
$L \leq 60$m	$2g$

Special consideration is to be given to ships with Froude number (F_n) > 0.4.

(2) Loads due to flooding on ship

For independent tanks, loads caused by the buoyancy of a fully submerged empty tank are to be considered in the design of anti-flotation chocks and the supporting structure in both the adjacent hull and tank structure.

① E.g. ISO 20421-1 Cryogenic vessels - Large transportable vacuum-insulated vessels - Part 1: Design, fabrication, inspection and testing and NB/T 47059 Tank containers for refrigerated liquefied gas.

4.2.8 Structural integrity

4.2.8.1 The structural design is to ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This is to take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.

4.2.8.2 The structural integrity of fuel containment systems can be demonstrated by compliance with 4.2.13 to 4.2.16 of this Section, as appropriate for the fuel containment system type.

4.2.8.3 For other fuel containment system types, that are of novel design or differ significantly from those covered by 4.2.13 to 4.2.16 of this Section, the structural integrity is to be demonstrated by compliance with 4.2.17.

4.2.9 Structural analysis

4.2.9.1 Analysis

(1) The design analyses are to be based on recognized principles of statics, dynamics and strength of materials.

(2) Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.

(3) When determining responses to dynamic loads, the dynamic effect is to be taken into account where it may affect structural integrity.

4.2.9.2 Load scenarios

(1) For each location or part of the fuel containment system to be considered and for each possible mode of failure to be analyzed, all relevant combinations of loads that may act simultaneously are to be considered.

(2) The most unfavourable scenarios and conditions for all relevant phases during construction, handling, testing and in service conditions are to be considered.

(3) When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses are to be calculated according to:

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\sum (\sigma_{x.dyn})^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\sum (\sigma_{y.dyn})^2}$$

$$\sigma_z = \sigma_{z.st} \pm \sqrt{\sum (\sigma_{z.dyn})^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\sum (\tau_{xy.dyn})^2}$$

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\sum (\tau_{xz.dyn})^2}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\sum (\tau_{yz.dyn})^2}$$

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ are static stress;

$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ are dynamic stress.

Each is to be determined separately from acceleration components and hull strain components due to deflection and torsion.

4.2.10 Design conditions

All relevant failure modes are to be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in 4.2.1.6, and the load scenarios are covered by 4.2.9.2 of this Section.

4.2.10.1 Ultimate design condition

(1) Structural capacity may be determined by testing or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of the Rules.

(2) Plastic deformation and buckling are to be considered.

(3) Analysis is to be based on characteristic load values as follows:

Permanent loads: Expected values

Functional loads: Specified values

Environmental loads: For wave loads: most probable largest load encountered during 10^8 wave encounters.

(4) For the purpose of ultimate strength assessment, the following material parameters apply:

① R_e ——specified minimum yield stress at room temperature, in N/mm^2. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

② R_m ——specified minimum tensile strength at room temperature, in N/mm^2.

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloy, the respective R_e and R_m of the welds, after any applied heat treatment, are to be used. In such cases, the transverse weld tensile strength is not to be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials are not to be incorporated in fuel containment systems.

The above properties are to correspond to the minimum specified mechanical properties of the material, including the weld metal in the as fabricated condition. Subject to special consideration by CCS, account may be taken of the enhanced yield stress and tensile strength at low temperature.

(5) The equivalent stress σ_c (von Mises, Huber) is to be determined by:

$$\sigma_c = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3\left(\tau_{xy}{}^2 + \tau_{xz}{}^2 + \tau_{yz}{}^2\right)}$$

where:

σ_x——total normal stress in x-direction;

σ_y——total normal stress in y-direction;

σ_z——total normal stress in z-direction;

τ_{xy}——total shear stress in x-y plane;

τ_{xz}——total shear stress in x-z plane;

τ_{yz}——total shear stress in y-z plane.

(6) Allowable stresses for materials other than those covered by 3.3.1 of the Rules are to be subject to approval by CCS in each case.

(7) Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

4.2.10.2 Fatigue design condition

(1) The fatigue design condition is the design condition with respect to accumulated cyclic loading.

(2) Where a fatigue analysis is required, the cumulative effect of the fatigue load is to comply with:

$$\sum \frac{n_i}{N_I} + \frac{n_{loading}}{N_{loading}} \leq C_w$$

where:

n_i——number of stress cycles at each stress level during the life of the tank;

N_i——number of cycles to fracture for the respective stress level according to the Wohler (S-N) curve;

$n_{loading}$——number of loading and unloading cycles during the life of the tank, not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle;

$N_{loading}$——number of cycles to fracture for the fatigue loads due to loading and unloading; and

C_w——maximum allowable cumulative fatigue damage ratio.

The fatigue damage is to be based on the design life of the tank but not less than 10^8 wave encounters.

(3) Where required, the fuel containment system is to be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the fuel containment system. Consideration is to be given to various filling conditions.

(4) Design S-N curves used in the analysis are to be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned. The S-N curves are to be based on a 97.6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable C_w values specified in 4.2.10.2 (12) to 4.2.10.2 (14) of this Section.

(5) Analysis is to be based on characteristic load values as follows:

Permanent loads: Expected values

Functional loads: Specified values or specified history

Environmental loads: Expected load history, but not less than 10^8 cycles

(6) The dynamic loading spectra shown in Figure 4.2.10.2(6) may be used for the estimation of the fatigue life. This simplified spectra includes 8 cyclic loading of which each cyclic loading and its corresponding number of cycles n_i are to be calculated as follows:

$$P_i = \frac{17-2i}{16} P_0$$

$$n_i = 0.9 \times 10^i$$

where:

i——i =1, 2, 3, 4, 5, 6, 7, 8.

P_0——loading at probability level Q=10^{-8}.

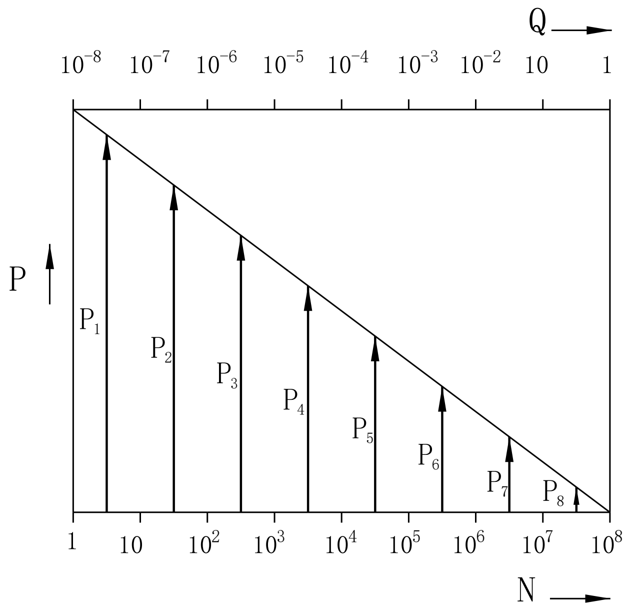


Figure 4.2.10.2 (6) Long-term Load Spectrum

If simplified dynamic loading spectra are used for the estimation of the fatigue life, those are to be specially considered by CCS.

(7) Where the size of the secondary barrier is reduced, as is provided for in 4.2.2.3 of this Section, fracture mechanics analyses of fatigue crack growth are to be carried out to determine:

① crack propagation paths in the structure, where necessitated by 4.2.10.2(12) to 4.2.10.2(14) of this Section, as applicable;

② crack growth rate;

③ the time required for a crack to propagate to cause a leakage from the tank;

④ the size and shape of through thickness cracks; and

⑤ the time required for detectable cracks to reach a critical state after penetration through the thickness.

The fracture mechanics is in general based on crack growth data taken as a mean value plus two standard deviations of the test data.

(8) Methods for fatigue crack growth analysis and fracture mechanics are to be based on recognized standards.

(9) In analyzing crack propagation, the largest initial crack not detectable by the inspection method applied is to be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable.

(10) In crack propagation analysis specified in 4.2.10.2(12) of this Section, the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in Figure 4.2.10.2 (10). Load distribution and sequence for longer periods, such as in 4.2.10.2(13) and 4.2.10.2 (14) of this Section, are to be approved by CCS.

(11) The arrangement is to comply with requirements of 4.2.10.2(12) to 4.2.10.2(14), as applicable.

(12) For failures that can be reliably detected by means of leakage detection:

C_w is to be less than or equal to 0.5.

Predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, is not to be less than 15 days unless different requirements apply for ships engaged in particular voyages.

(13) For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections:

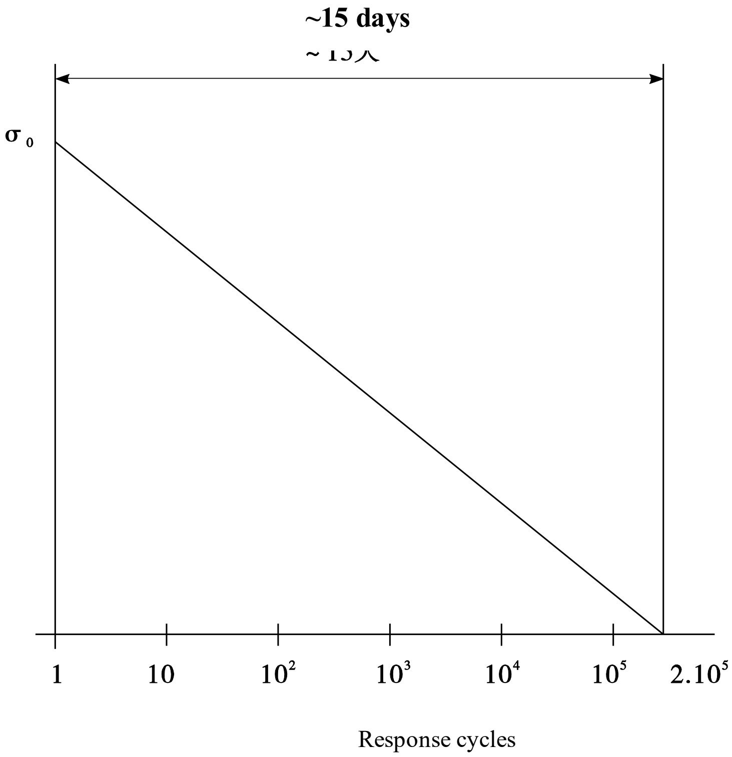
C_w is to be less than or equal to 0.5.

Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, is not to be less than three times the inspection interval.

(14) In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria is to be applied as a minimum:

C_w is to be less than or equal to 0.1.

Predicted failure development time, from the assumed initial defect until reaching a critical state, is not to be less than three times the lifetime of the tank



σ_0= most probable maximum stress over the life of the ship

Response cycle scale is logarithmic; the value of 2×10^5 is given as an example of estimate.

Figure 4.2.10.2 (10) – Simplified load distribution

4.2.10.3 Accidental design condition

(1) The accidental design condition is a design condition for accidental loads with extremely low probability of occurrence.

(2) Analysis is to be based on characteristic load values as follows:

Permanent loads: Expected values

Functional loads: Specified values

Environmental loads: Specified values

Accidental loads: Specified values or expected values

Loads mentioned in 4.2.7.3 (3) ⑧ and 4.2.7.5 of this Section need not be combined with each other or with wave-induced loads.

4.2.11 Materials and construction

4.2.11.1 Materials forming ship structure

(1) To determine the grade of plate and sections used in the hull structure, a temperature calculation is to be performed for all tank types. The following assumptions are to be made in this calculation:

① The primary barrier of all tanks is to be assumed to be at the liquefied gas fuel temperature;

② In addition to ① above, where a complete or partial secondary barrier is required, it is to be assumed to be at the liquefied gas fuel temperature at atmospheric pressure for any one tank only;

③ For worldwide service, ambient temperatures are to be taken as 5°C for air and 0°C for seawater. Higher values may be accepted by CCS for ships operating in restricted areas and conversely, lower values may be imposed by CCS for ships trading to areas where lower temperatures are expected during the winter months;

④ Still air and sea water conditions are to be assumed, i.e. no adjustment for forced convection；

⑤ Degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations is to be assumed;

⑥ The cooling effect of the rising boil-off vapour from the leaked liquefied gas fuel is to be taken into account where applicable;

⑦ Credit for hull heating may be taken in accordance with 4.2.11.1 (3) of this Section, provided the heating arrangements are in compliance with 4.2.11.1(4) of this Section;

⑧ No credit is to be given for any means of heating, except as described in 4.2.11.1 (3);

⑨ For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

(2) The materials of all hull structures for which the calculated temperature in the design condition is below 0℃, due to the influence of liquefied gas fuel temperature, is to be in accordance with Table 3.3.1.1 (5) of the Rules. This includes hull structure supporting the fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

(3) Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Table 3.3.1.1 (5) of the Rules. In the calculations required in 4.2.11.1 (1), credit for such heating may be taken in accordance with the following principles:

① for any transverse hull structure;

② for longitudinal hull structure referred to in 4.2.11.1 (2) of this Section where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of plus 5℃ for air and 0℃ for seawater with no credit taken in the calculations for heating; and

③ as an alternative to ② above, for longitudinal bulkhead between fuel tanks, credit may be taken for heating provided the materials remain suitable for a minimum design temperature of minus 30°C, or a temperature 30°C lower than that determined by 4.2.11.1 (1) of this Section, whichever is less. In this case, the ship's longitudinal strength is to comply with CCS Rules for Classification of Sea-going Steel Ships or CCS Rules for the Construction of Inland Waterways Steel Ships for both when those bulkhead(s) are considered effective and not.

(4) The means of heating referred to in 4.2.11.1 (3) of this Section is to comply with the following:

① the heating system is to be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to no less than 100% of the theoretical heat requirement;

② the heating system is to be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 4.2.11.1 (3) ① are to be supplied from the emergency source of electrical power; and

4.2.11.2 Materials of primary and secondary barriers

(1) Metallic materials used in the construction of primary and secondary barriers not forming the hull, are to be suitable for the design loads that they may be subjected to, and be in accordance with Table 3.3.1.1 (1), Table 3.3.1.1 (2) or Table 3.3.1.1 (3).

(2) Materials, either non-metallic or metallic but not covered by Table 3.3.1.1 (1), Table 3.3.1.1 (2) and Table 3.3.1.1 (3), used in the primary and secondary barriers may be approved by CCS considering the design loads that they may be subjected to, their properties and their intended use.

(3) Where non-metallic materials, including composites, are used for or incorporated in the primary or secondary barriers, they are to be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

① compatibility with the liquefied gas fuels;

② aging;

③ mechanical properties;

④ thermal expansion and contraction;

⑤ abrasion;

⑥ cohesion;

⑦ resistance to vibrations;

⑧ resistance to fire and flame spread; and

⑨ resistance to fatigue failure and crack propagation.

(4) The above properties, where applicable, are to be tested for the range between the expected maximum temperature in service and 5℃ below the minimum design temperature, but not lower than minus 196℃.

(5) Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes are also to be tested as described above.

(6) Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier.

4.2.11.3 Thermal insulation and other materials used in fuel containment systems

(1) Load-bearing thermal insulation and other materials used in fuel containment systems are to be suitable for the design loads.

(2) Thermal insulation and other materials used in fuel containment systems are to have the following properties, as applicable, to ensure that they are adequate for the intended service:

① compatibility with the liquefied gas fuels;

② solubility in the liquefied gas fuel;

③ absorption of the liquefied gas fuel;

④ shrinkage;

⑤ aging;

⑥ closed cell content;

⑦ density;

⑧ mechanical properties, to the extent that they are subjected to liquefied gas fuel and other loading effects, thermal expansion and contraction;

⑨ abrasion;

⑩ cohesion;

⑪ thermal conductivity;

⑫ resistance to vibrations;

⑬ resistance to fire and flame spread; and

⑭ resistance to fatigue failure and crack propagation.

(3) The above properties, where applicable, are to be tested for the range between the expected maximum temperature in service and 5℃ below the minimum design temperature, but not lower than minus 196℃.

(4) Due to location or environmental conditions, thermal insulation materials are to have suitable properties of resistance to fire and flame spread and are to be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck and in way of tank cover penetrations, it is to have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

(5) Thermal insulation that does not meet recognized standards for fire resistance may be used in fuel storage hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal.

(6) Testing for thermal conductivity of thermal insulation is to be carried out on suitably aged samples.

(7) Where powder or granulated thermal insulation is used, measures are to be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the liquefied gas fuel containment system.

4.2.12 Construction processes

4.2.12.1 Weld joint design

(1) All welded joints of the shells of independent tanks are to be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds are also to be designed with full penetration.

Independent tanks of type A or type B, primarily constructed of plane surfaces, are also to comply with the following requirements:

① Welded corners (i.e. corners made of weld metal) are not to be used in the main tank shell construction, i.e. corners between shell side (sloped plane surfaces parallel to hopper or top side inclusive if any) and bottom or top of the tank, and between tank end transverse bulkheads and bottom, top or shell sides (sloped plane surfaces inclusive if any) of the tank. Instead, tank corners which are constructed using bent plating aligned with the tank surfaces and connected with in-plane welds are to be used;

②Tee welds can be accepted for other localized constructions of the shell such as suction well, sump, dome, etc. where tee welds of full penetration type are also to be used.

(2) Welding joint details for type C independent tanks and for the liquid-tight primary barriers of type B independent tanks primarily constructed of curved surfaces are to be as follows:

① All longitudinal and circumferential joints are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed except from very small process pressure vessels[①]. Other edge preparations permitted, depending on the results of the tests carried out at the approval of the welding procedure. For connections of tank shell to a longitudinal bulkhead of type C bilobe tanks, tee welds of the full penetration type may be accepted.

② The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings is to be designed according to a standard acceptable to CCS. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles are to be full penetration welds.

4.2.12.2 Design for gluing and other joining processes

(1) The design of the joint to be glued (or joined by some other process except welding) is to take account of the strength characteristics of the joining process.

4.2.13 Type A independent tanks

4.2.13.1 Design basis

(1) Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures according to recognized standards. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_0 is to be less than 0.07 MPa.

(2) A complete secondary barrier is to be required as defined in 4.2.3 of this Section.

4.2.13.2 Structural analysis

(1) A structural analysis is to be performed taking into account the internal pressure as indicated in 4.2.7.3 (3) ① of this Section, and the interaction loads with the supporting and keying system as well as a reasonable part of the hull.

(2) For parts, such as structure in way of supports, not otherwise covered in the Rules, stresses are to be determined by direct calculations, taking into account the loads referred to in 4.2.7.2 to 4.2.7.5 of this Section as far as applicable, and the ship deflection in way of supports.

(3) The tanks with supports are to be designed for the accidental loads specified in 4.2.7.5 of this Section. These loads need not be combined with each other or with environmental loads.

4.2.13.3 Ultimate design condition

(1) For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, are not to exceed the lower of $R_m/2.66$ or $R_e/1.33$ for nickel steel, carbon-manganese steel, austenitic steel and aluminium alloy, where R_m and R_e are defined in 4.2.10.1 (4) of this Section. However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c may be increased over that indicated above to a stress acceptable to CCS. Calculations are to take into account the effects of bending, shear, axial and torsional deformation as well as the hull/fuel tank interaction forces due to the deflection of the hull structure and fuel tank bottoms.

(2) Tank boundary cantlings are to meet at least CCS' requirements for deep tanks taking into account

① For vacuum insulated tanks without manhole, the longitudinal and circumferential joints are to meet the aforementioned requirements, except for the erection weld joint of the outer shell, which may be a one-side welding with backing rings.

the internal pressure as indicated in 4.2.7.3 (3) ① of this Section and any corrosion allowance required by 4.2.1.7.

(3) The fuel tank structure is to be reviewed against potential buckling.

4.2.13.4 Accidental design condition

(1) The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in 4.2.7.5 and 4.2.1.6 (3) of this Section, as relevant.

(2) When subjected to the accidental loads specified in 4.2.7.5, the stress is to comply with the acceptance criteria specified in 4.2.13.3, modified as appropriate, taking into account their lower probability of occurrence.

4.2.14 Type B independent tanks

4.2.14.1 Design basis

(1) Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks), the design vapour pressure P_0 is to be less than 0.07 MPa.

(2) A partial secondary barrier with a small protection system is to be provided. The small leak protection system is to be designed according to 4.2.3 of this Section.

4.2.14.2 Structural analysis

(1) The effects of all dynamic and static loads are to be used to determine the suitability of the structure with respect to:

① plastic deformation;

② buckling;

③ fatigue failure; and

④ crack propagation.

(2) Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, is to be carried out.

(3) A three-dimensional analysis is to be carried out to evaluate the stress levels, including interaction with the hull. The model for this analysis is to include the liquefied gas fuel tank with its supporting and keying system, as well as a reasonable part of the hull.

(4) A complete analysis of the particular ship accelerations and motions in irregular waves, and of the response of the ship and its liquefied gas fuel tanks to these forces and motions, is to be performed unless the data is available from similar ships.

4.2.14.3 Ultimate design condition

(1) For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses are not to exceed:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

$$\sigma_L + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

where:

σ_m ——equivalent primary general membrane stress;

σ_L——equivalent primary local membrane stress;

σ_b——equivalent primary bending stress;

σ_g——equivalent secondary stress;

f——the lesser of (R_m/A) or (R_e/B); and

F——the lesser of (R_m/C) or (R_e/D).

with R_m and R_e are defined as above. With regard to the stresses σ_m, σ_L, σ_b and σ_g, see also the definition of stress categories in 4.2.14.7 of this Section.

(2) The values A and B are to have at least the following minimum values:

Table 4.2.14.3（2）

	Nickel steel and carbon-manganese steel	Austenitic steel	Aluminium alloy
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

(3) The above figures may be altered considering the design condition accepted by the Administration.

(4) For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis are not to exceed:

① for nickel steel and carbon-manganese steel, the lesser of R_m /2 or R_e /1.2;

② for austenitic steel, the lesser of R_m /2.5 or R_e /1.2; and

③ for aluminium alloy, the lesser of R_m /2.5 or R_e /1.2.

(5) The above figures may be amended considering the locality of the stress, stress analysis methods and design condition considered in acceptance with the Administration.

(6) The thickness of the skin plate and the size of the stiffener are not to be less than those required for type A independent tanks.

(7) Buckling strength analyses of fuel tanks subject to external pressure and other loads causing compressive stresses are to be carried out in accordance with recognized standards. The method is adequately to account for the difference in theoretical and actual buckling stress as a result of plate out of plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.

4.2.14.4 Fatigue design condition

(1) Fatigue and crack propagation assessment is to be performed in accordance with 4.2.10.2 of this Section. The acceptance criteria is to comply with 4.2.10.2 (12), 4.2.10.2 (13) or 4.2.10.2 (14) of this Section, depending on the detectability of the defect.

(2) Fatigue analysis is to consider construction tolerances.

(3) Where deemed necessary by CCS, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

4.2.14.5 Accidental design condition

(1) The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in 4.2.7.5 and 4.2.1.6 (3) of this Section, as relevant.

(2) When subjected to the accidental loads specified in 4.2.7.5 of this Section, the stress is to comply with the acceptance criteria specified in 4.2.14.3, modified as appropriate taking into account their lower probability of occurrence.

4.2.14.6 Marking

Any marking of the pressure vessel is to be achieved by a method that does not cause unacceptable local stress raisers.

4.2.14.7 Stress categories

(1) For the purpose of stress evaluation, stress categories are defined in this Section as follows:

① Normal stress is the component of stress normal to the plane of reference;

② Membrane stress is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration;

③ Bending stress is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress;

④ Shear stress is the component of the stress acting in the plane of reference;

⑤ Primary stress is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations;

⑥ Primary general membrane stress is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding;

⑦ Primary local membrane stress arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:

$$S_1 \leq 0.5\sqrt{Rt}\text{; and}$$
$$S_2 \geq 2.5\sqrt{Rt}$$

where:

S_1——distance in the meridional direction over which the equivalent stress exceeds $1.1f$;

S_2——distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded;

R——mean radius of the vessel;

t——wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded; and

f——allowable primary general membrane stress.

⑧ Secondary stress is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

4.2.15 Type C independent tanks

4.2.15.1 Design basis

(1) The design basis for type C independent tanks is based on pressure vessel criteria including fracture mechanics and crack propagation criteria. The minimum design pressure defined in 4.2.15.1 (2) of this Section is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.

(2) The design vapour pressure is not to be less than:

$$P_0 = 0.2 + AC(\rho_r)^{1.5} \text{ MPa}$$

where:

$$A = 0.00185\left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with:

σ_m——design primary membrane stress;

$\Delta\sigma_A$——allowable dynamic membrane stress (double amplitude at probability level Q=10^{-8}) and equal to:

$\Delta\sigma_A$=55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel;

$\Delta\sigma_A$=25 N/mm^2 for aluminium alloy (5083-O);

C——a characteristic tank dimension to be taken as the greatest of the following:

h, $0.75b$ or $0.45l$

with:

h——height of tank (dimension in ship's vertical direction), in m;

b——width of tank (dimension in ship's transverse direction), in m;

l——length of tank (dimension in ship's longitudinal direction), in m;

ρ_r——the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature.

4.2.15.2 Shell thickness

(1) In considering the shell thickness, the following apply:

① for pressure vessels, the thickness calculated according to 4.2.15.2 (4) of this Section is to be considered as a minimum thickness after forming, without any negative tolerance.

② The minimum thickness including corrosion allowance, of shell and heads of pressure vessels after forming, is to be:

not less than 5 mm for carbon manganese steel and nickel steel;

not less than 3 mm for austenitic steel;

not less than 7 mm for aluminium alloy.

③ the welded joint efficiency factor to be used in the calculation according to 4.2.15.2 (4) of this Section is to be 0.95 when the inspection and the non-destructive testing referred to in 13.3.6.4 are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels, CCS may accept partial non-destructive examinations, but not less than those of 13.3.6.4, on such depending factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 is to be adopted. For special materials, the above-mentioned factors are to be reduced, depending on the specified mechanical properties of the welded joint.

(2) The design liquid pressure defined in 4.2.7.3 (4) of this Section is to be taken into account in the internal pressure calculations.

(3) The design external pressure P_e, used for verifying the buckling of the pressure vessels, is not to be less than that given by:

$$P_e = P_1 + P_2 + P_3 + P_4 \quad \text{(MPa)}$$

where:

P_1——setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves, P_1 is to be specially considered, but is not in general to be taken as less than 0.025 MPa;

P_2——the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere $P_2 = 0$;

P_3——compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both are to be taken into account;

P_4——external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$.

(4) The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 4.2.7.3 (3) ① of this Section, including flanges, are to be determined. These calculations are in all cases to be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels are to be reinforced in accordance with a recognized standard.

(5) Stress analysis in respect of static and dynamic loads is to be performed as follows:

(a) pressure vessel scantlings are to be determined in accordance with 4.2.15.2 (1) to 4.2.15.2 (4) and 4.2.15.3.

(b) calculations of the loads and stresses in way of the supports and the shell attachment of the support are to be made. Loads referred to in 4.2.7.2 to 4.2.7.5 are to be used, as applicable. In special cases, a fatigue analysis may be required by CCS.

Where bolts are used for the connection of supporting structure to hull structure, the bolts and stoppers (if any) are to be checked for their strength, and the loading conditions may refer to the calculation conditions mentioned in Annex 3 or Annex 4 of the Rules. Checking of bolt strength is to comply with 3.2.5, Section 2, Chapter 3, PART THREE of CCS Rules for Classification of Sea-going Steel Ships or standards① accepted by CCS, as relevant.

If required② by CCS, secondary stresses and thermal stresses are to be specially considered.

① E.g. VDI 2230 System calculations of high-strength bolted connections and GB/T 3098.1 Mechanical properties of fasteners - Bolts, screws and studs.

② E.g. for vacuum insulated type C tanks, secondary stresses may be considered in strength checking in way of the sudden structure change connecting supporting structure to tank body; and thermal stresses are in general considered in strength checking of saddles and anti-flotation arrangements for single-layer-foam insulated type C tanks.

4.2.15.3 Ultimate design condition

(1) For type C independent tanks, the allowable stresses are not to exceed:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5f$$

$$\sigma_L+\sigma_b \leq 1.5f$$

$$\sigma_m+\sigma_b \leq 1.5f$$

$$\sigma_m+\sigma_b+\sigma_g \leq 3.0f$$

$$\sigma_L+\sigma_b+\sigma_g \leq 3.0f$$

where:

σ_m——equivalent primary general membrane stress;

σ_L——equivalent primary local membrane stress;

σ_b——equivalent primary bending stress;

σ_g——equivalent secondary stress;

f——the lesser of R_m /A or R_e /B,

with R_m and R_e are defined as above. With regard to the stresses σ_m, σ_L, σ_g and σ_b, see also the definition of stress categories defined above. The values of A and B are to have at least the following minimum values:

Table 4.2.15.3（1）

	Nickel steel and carbon-manganese steel	Austenitic steel	Aluminium alloy
A	3	3.5	4
B	1.5	1.5	1.5

(2) The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses are to be based on calculations using accepted pressure vessel buckling theory and are to adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

4.2.15.4 Fatigue design condition

(1) For type C independent tanks, CCS may require additional verification to check their compliance with 4.2.15.1 (1) of this Section, regarding static and dynamic stress depending on the tank size, the configuration of the tank and arrangement of its supports and attachments.

(2) For vacuum insulated tanks, special attention is to be made to the fatigue strength of the support design and special considerations are also to be made to the inspection possibilities between the inside and outer shell.

4.2.15.5 Accidental design condition

(1) The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in 4.2.7.5 and 4.2.1.6 (3) of this Section, as relevant.

(2) When subjected to the accidental loads specified in 4.2.7.5, the stress is to comply with the acceptance criteria specified in 4.2.15.3 (1), modified as appropriate, taking into account their lower probability of occurrence.

4.2.15.6 Marking

The required marking of the pressure vessel is to be achieved by a method that does not cause unacceptable local stress raisers.

4.2.16 Membrane tanks

4.2.16.1 Design basis

① The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

② A systematic approach, based on analysis and testing, is to be used to demonstrate that the system will provide its intended function in consideration of the identified in service events as specified in 4.2.16.2(1) of this Section.

③ A complete secondary barrier is to be provided. The secondary barrier is to be designed according to 4.2.3 of this Section.

④ The design vapour pressure P_0 is normally not to exceed 0.025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_0 may be increased to a higher value but less than 0.070 MPa.

⑤ The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

⑥ The thickness of the membranes is normally not to exceed 10 mm.。

⑦ The circulation of inert gas throughout the primary and the secondary insulation spaces, in accordance with 4.8.2 of this Chapter, is to be sufficient to allow for effective means of gas detection.

4.2.16.2 Design considerations

(1) Potential incidents that could lead to loss of fluid tightness over the life of the membranes are to be evaluated. These include, but are not limited to:

① Ultimate design events:

(a) tensile failure of membranes;

(b) compressive collapse of thermal insulation;

(c) thermal ageing;

(d) loss of attachment between thermal insulation and hull structure;

(e) loss of attachment of membranes to thermal insulation system;

(f) structural integrity of internal structures and their associated supporting structures; and

(g) failure of the supporting hull structure.

② Fatigue design events:

(a) fatigue of membranes including joints and attachments to hull structure;

(b) fatigue cracking of thermal insulation;

(c) fatigue of internal structures and their associated supporting structures; and

(d) fatigue cracking of inner hull leading to ballast water ingress.

③ Accidental design events:

(a) accidental mechanical damage (such as dropped objects inside the tank while in service);

(b) accidental over pressurization of thermal insulation spaces;

(c) accidental vacuum in the tank; and

(d) water ingress through the inner hull structure.

(2) Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

(3) The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the liquefied gas fuel containment system are to be established during the design development in accordance with 4.2.16.1 ② of this Section.

4.2.16.3 Loads and load combinations

Particular consideration is to be paid to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the liquefied gas fuel tank, the sloshing effects, to hull vibration effects, or any combination of these events.

4.2.16.4 Structural analyses

(1) Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the fuel containment and associated structures and equipment noted in 4.2.5 of this Section are be to performed. The structural analysis is to provide the data required to assess each failure mode that has been identified as critical for the fuel containment system.

(2) Structural analyses of the hull are to take into account the internal pressure as indicated in 4.2.7.3 （3） ① of this Section. Special attention is to be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

(3) The analyses referred to in 4.2.16.4 (1) and 4.2.16.4 (2) of this Section are to be based on the particular motions, accelerations and response of ships and fuel containment systems.

4.2.16.5 Ultimate design condition

(1) The structural resistance of every critical component, sub-system or assembly is to be established in accordance with 4.2.16.1② of this Section, for in-service conditions.

(2) The choice of strength acceptance criteria for the failure modes of the fuel containment system, its attachments to the hull structure and internal tank structures is to reflect the consequences associated with the considered mode of failure.

(3) The inner hull scantlings are to meet the requirements for deep tanks, taking into account the internal pressure as indicated in 4.2.7.3 (3) ① and the specified appropriate requirements for sloshing load as defined in 4.2.7.4 (3) of this Section.

4.2.16.6 Fatigue design condition

(1) Fatigue analysis is to be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

(2) The fatigue calculations are to be carried out in accordance with 4.2.10.2 of this Section, with relevant requirements depending on:

① the significance of the structural components with respect to structural integrity; and

② availability for inspections.

(3) For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w is to be less than or equal to 0.5.

(4) Structural elements subject to periodic inspections, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, are to satisfy the fatigue and fracture mechanics requirements stated in 4.2.10.2 (13) of this Section.

(5) Structural elements not accessible for in-service inspections, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, are to satisfy the fatigue and fracture mechanics requirements stated in 4.2.10.2 (14) of this Section.

4.2.16.7 Accidental design condition

(1) The containment system and the supporting hull structure are to be designed for the accidental loads specified in 4.2.7.5 of this Section. These loads need not be combined with each other or with environmental loads.

(2) Additional relevant accidental scenarios are to be determined based on a risk analysis. Particular attention is to be paid to securing devices inside of tanks.

4.2.17 Limit state design for novel concepts

4.2.17.1 Fuel containment systems that are of a novel configuration that cannot be designed according to 4.2.13 to 4.2.16 of this Section are to be designed according to 4.2.1 to 4.2.12 of this Section, as applicable. Fuel containment system design according to this Section is to be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed according to 4.2.13 to 4.2.16 of this Section.

4.2.17.2 The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 4.2.1.6 of this Section. A limit state can be defined as a condition beyond which the structure or part of a structure no longer satisfies the requirements.

4.2.17.3 For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:

(1) Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation, under intact (undamaged) conditions;

(2) Fatigue limit states (FLS), which correspond to failure due to the effect of time varying (cyclic) loading;

(3) Accident limit states (ALS), which concern the ability of the structure to resist accidental situations.

4.2.17.4 The procedure and relevant design parameters of the limit state design are to comply with the standards for the use of limit state methodologies in the design of fuel containment systems of novel configuration (LSD Standard), as set out in ANNEX 2 of the Rules.

Section 3 PORTABLE LIQUEFIED GAS FUEL TANKS

4.3.1 General requirements

4.3.1.1 The design of the tank is to comply with 4.2.15 of this Chapter. The tank support (container frame or truck chassis) is to be designed for the intended purpose.

4.3.1.2 Portable fuel tanks are to be located in dedicated areas fitted with:

(1) mechanical protection of the tanks depending on location and cargo operation;

(2) if located on open deck, spill protection and water spray systems for cooling; and

(3) if located in an enclosed space, the space is to be considered as a tank connection space.

4.3.1.3 Portable tanks are to be secured to the deck while connected to ship systems. The arrangement for supporting and fixing the tanks is to be designed for the maximum expected static and dynamic inclinations, as well as the maximum expected values of acceleration, taking into account the ship characteristics and the position of the tanks.

4.3.1.4 Consideration is to be given to the strength and the effect of the portable fuel tanks on the ship stability.

4.3.1.5 Connections to the ship's fuel piping system are to be made by means of approved hoses[①] or other suitable means designed to provide sufficient flexibility.

4.3.1.6 Arrangements are to be provided to limit the quantity of fuel spilled in case of inadvertent disconnection or rupture of the non-permanent connections.

These arrangements include but are not limited to:

（1）Gas detectors satisfying 12.3.1 of the Rules where the non-permanent connection is located in an enclosed or semi-enclosed space; or

（2）Pressure, temperature or flow monitoring systems or any combinations thereof provided in the non-permanent connections.

The safety systems of portable fuel tanks is to be immediately activated on detection of fuel leakage by these arrangements.

4.3.1.7 The pressure relief system of portable tank is to be connected to a fixed venting system.

Such connection may be not required for ships engaged on domestic voyages, provided that:

（1）The portable tank, having an external size not beyond a 40' container, is located on open deck, and the gas released from pressure relief systems will not cause cryogenic damages to the ship and tank as well as the structural attachments;

（2）Vent piping is to be designed and arranged according to 4.5.2.7 to 4.5.2.12 of this Chapter;

（3） In addition, in the case of detachable vent piping, effective means are to be provided to ensure the gas tightness in way of the pipe connections to prevent leakage or loosening at the connections due to temperature variation, gas flow pressure or ship motions.

4.3.1.8 Control and monitoring systems for portable tanks are to be integrated in the ship control and monitoring system. The safety system for portable tanks is to be integrated in the ship safety system (e.g. shutdown systems for tank valves, leak/gas detection systems).

4.3.1.9 Safe accesses to tank connections for the purpose of inspection and maintenance are to be ensured.

4.3.1.10 After connection to the ship fuel piping system,

(1) with the exception of the pressure relief system in 4.3.1.7 of this Section, each portable tank is to be capable of being isolated at any time;

Where two or more portable tanks are served for fuel supplying simultaneously, the pipe branches of each tank are to be arranged separately; and a holding back arrangement is to be provided at the upstream of the manifold provided that any fuel back-flow may occur within the pipe branches.

(2) isolation of one tank is not to impair the availability of the remaining portable tanks; and

(3) the tank is not to exceed its filling limits as given in Section 6 of this Chapter.

4.3.1.11 In addition, for LNG tank containers used as a portable fuel tank,

(1) The design, construction,testing and marking are to comply with CCS Rules for Certification of

---

① Hoses are to comply with the standards accepted by CCS, e.g. SY/T 6986.2 Installation and Equipment for Liquefied Natural Gas - Design and Testing of Marine Transfer Systems - Part 2: Design and Testing of Transfer Hoses, or BS EN1474-2 Installation and Equipment for Liquefied Natural Gas -Design and Testing of Marine Transfer Systems Part 2: Design and Testing of Transfer Hoses.

Freight Containers or recognized standards[①] accepted by CCS, as relevant.

(2) Vacuum-insulated tanks are to comply with 4.2.2.5 of this Chapter. And if the shell is made of low temperature material, the members in connection with it, such as collar plates and connecting pieces, are to be also made of low temperature material having design temperature not greater than that of the shell.

(3) It is to be shown by a heat transfer calculation or test that the frame of a LNG tank container will not be exposure of unacceptable low temperature due to fuel leakage, unless the frame is to be made of low temperature material.

(4) The connection area and pipes of a LNG tank container to the ship's fuel piping are to provide an equivalent level of safety of that of the bunkering station and bunkering lines specified in Chapter 5 of the Rules.

(5) Where LNG tank containers are stacked, a risk assessment is to be conducted for all risks which may affect their safe use, and the relevant reports are to be approved by CCS.

Section 4 CNG FUEL CONTAINMENT SYSTEMS

4.4.1 General requirements

4.4.1.1 The storage tanks to be used for CNG are to be certified and approved by CCS.

4.4.1.2 Tanks for CNG are to be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 4.5.2.7 and 4.5.2.8 of this Chapter.

4.4.1.3 Adequate means are to be provided to depressurize the tank in case of a fire which can affect the tank.

4.4.1.4 Storage of CNG in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by CCS provided the following is fulfilled in addition to 4.1.3.4, 4.1.3.7 and 4.1.3.8:

(1) Adequate means are to be provided to depressurize the tank in case of a fire which can affect the tank;

(2) All surfaces within such enclosed spaces containing the CNG storage are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

(3) A fixed fire-extinguishing system is installed in the enclosed spaces containing the CNG storage. Special consideration is to be given to the extinguishing of jet-fires.

Section 5 PRESSURE RELIEF SYSTEMS

4.5.1 General requirements

4.5.1.1 All fuel storage tanks are to be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried. Fuel storage hold spaces, interbarrier spaces and tank connection spaces, which may be subject to pressures beyond their design capabilities, are also to be provided with a suitable pressure relief system.

① E.g. NB/T 47059 Tank containers for refrigerated liquefied gas and International Maritime Dangerous Goods Code (IMDG Code).

4.5.1.2 Tank pressure release systems are to be independent of the pressure control system specified in Section 7 of this Chapter and other functional piping.

4.5.1.3 Fuel tanks which may be subject to external pressures above their design pressure are to be fitted with vacuum protection systems.

4.5.2 Pressure relief systems for LNG tanks

4.5.2.1 If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space is to be protected by a pressure relief device, and

（1）the pressure release device is to be connected to a vent system if the tanks are located below deck;

（2）on open deck, a direct release into the atmosphere may be accepted by the Administration for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.

4.5.2.2 Fuel tanks are to be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

4.5.2.3 Interbarrier spaces are to be provided with pressure relief devices. For membrane systems, the designer is to demonstrate adequate sizing of interbarrier space PRVs.

4.5.2.4 The setting of the PRVs is not to be higher than the maximum vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

4.5.2.5 The following temperature requirements apply to PRVs fitted to pressure relief systems:

(1) PRVs on fuel tanks with a design temperature below 0°C are to be designed and arranged to prevent their becoming inoperative due to ice formation;

(2) The effects of ice formation due to ambient temperatures are to be considered in the construction and arrangement of PRVs;

(3) PRVs are to be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and

(4) Sensing and exhaust lines on pilot operated relief valves are to be of suitably robust construction to prevent damage.

4.5.2.6 In the event of a failure of one fuel tank PRV, a safe means of emergency isolation is to be available, and:

(1) procedures are to be available and included in the operation manual;

(2) the procedures are to allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks are to be included to this effect; and

(3) isolation of the PRV is to be carried out under the supervision of the master. This action is to be recorded in the ship log and at the PRV.

4.5.2.7 Each pressure relief valve installed on LNG tank is to be connected to a venting system, which is to be:

(1) so constructed that the discharge will be unimpeded and be directed vertically upwards at the exit;

(2) arranged to minimize the possibility of water or snow entering the vent system;

(3) arranged such that the height of vent exits is normally not to be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways.

If this is impracticable for inland waterways ships, the height of vent exits is to be 3 m above the weather deck and the working areas and walkways (if applicable) where they are located.

4.5.2.8 The outlet from the pressure relief valves is normally to be located at least 10 m from the nearest:

(1) air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and

(2) exhaust outlet from the nearest machinery installations.

If this is impracticable for inland waterways ships, the distance mentioned above may be reduced from 10 m to 5 m.

4.5.2.9 All other fuel gas vent outlets are also to be arranged in accordance with 4.5.2.7 and 4.5.2.8 of this Section. Means are to be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

4.5.2.10 In the vent piping system, means for draining liquid from places where it may accumulate are to be provided. The PRVs and piping are to be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

4.5.2.11 Suitable protection screens of not more than 13 mm square mesh are to be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.

4.5.2.12 All vent piping is to be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

4.5.2.13 PRVs are to be connected to the highest part of the fuel tank. PRVs are to be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL), under conditions of 15° list and 0.015L trim, where L is the length of ship.

4.5.3 Sizing of pressure relieving system

4.5.3.1 Sizing of pressure relief valves

(1) PRVs are to have a combined relieving capacity for each liquefied gas fuel tank to discharge the greater of the following, with not more than a 20% rise in fuel tank pressure above the MARVS:

① the maximum capacity of the fuel tank inerting system if the maximum attainable working pressure of the fuel tank inerting system exceeds the MARVS of the fuel tanks; or

② vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0.82}\ \mathrm{m^3/s}$$

where:

Q——minimum required rate of discharge of air at standard conditions of 273.15 Kelvin (K) and 0.1013 MPa;

F——fire exposure factor for different fuel tank types:

F= 1.0 for tanks without insulation located on deck;

F= 0.5 for tanks above the deck when insulation is approved by CCS. (Approval will be based on the use of a fireproof material, the thermal conductance of insulation, and its stability under fire exposure);

F= 0.5 for uninsulated independent tanks installed in holds;

F= 0.2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

F= 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds); and

F=0.1 for membrane tanks.

For independent tanks partly protruding through the weather decks, the fire exposure factor is to be determined on the basis of the surface areas above and below deck.

G——gas factor according to formula:

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

where:

T—— temperature in Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L—— latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D—— a constant based on relation of specific heats k and is calculated as follows:

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

where:

k—— ratio of specific heats at relieving conditions, and the value of which is between 1.0 and 1.0. If k is not known, D = 0.606 is to be used;

Z—— compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 is to be used;

M—— molecular mass of the product;

A—— external surface area of the tank, in m^2, as for different tank types, as shown in Figure 4.5.3.1（1）.

Prismatic tanks are to comply with the followings:

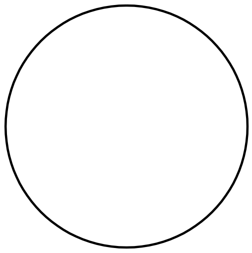
（a）L_{min}, for non-tapered tanks, is the smaller of the horizontal dimensions of the flat bottom of the tank. For tapered tanks, as would be used for the forward tank, L_{min} is the smaller of the length and the average width;

（b）For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is equal to or less than $L_{min}/10$:

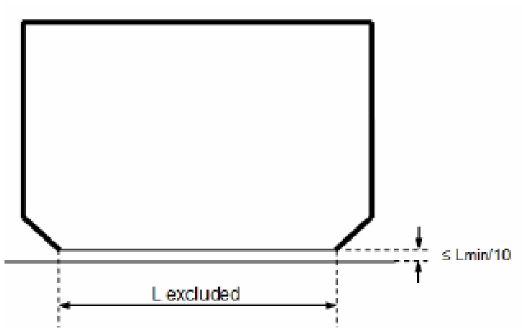
A = external surface area minus flat bottom surface area;

（c）For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than $L_{min}/10$:

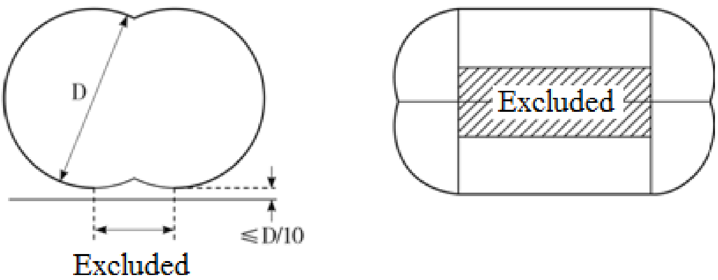
A = external surface area.



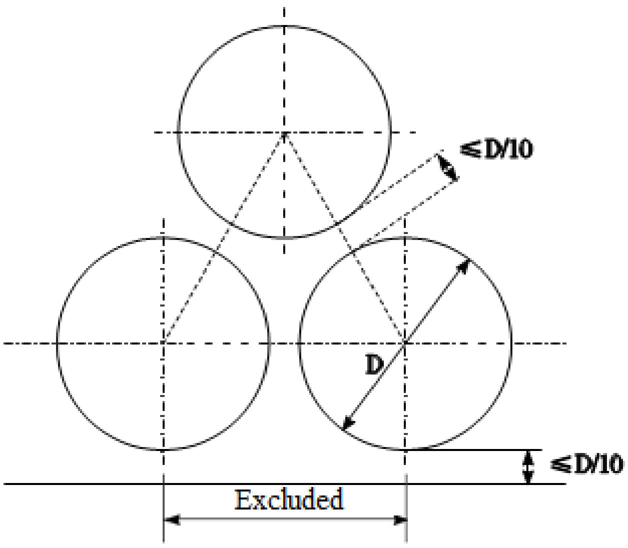
Cylindrical tanks spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks



Prismatic tanks



Bilobe tanks



Horizontal cylindrical tanks arrangement

Figure 4.5.3.1 (1)

(2) For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by cofferdams or surrounded by ship spaces with no fire load, the following applies:

If the pressure relief valves have to be sized for fire loads, the fire factor F accordingly may be reduced to the following values:

$$F = 0.5 \text{ to } F = 0.25$$

$$F = 0.2 \text{ to } F = 0.1$$

The minimum fire factor is F=0.1.

③ The required mass flow of air at relieving conditions is given by:

$$M_{\text{air}} = Q \cdot \rho_{air} \ \text{ kg/s}$$

where:

ρ_{air}—— density of air, ρ_{air}=1.293 kg/m^3 (air at 273.15 K, 0.1013 MPa).

4.5.3.2 Sizing of vent pipe systems

(1) Pressure losses upstream and downstream of the PRVs, are to be taken into account when determining their size to ensure the flow capacity required by 4.5.3.1 of this Section.

(2) Upstream pressure losses

① the pressure drop in the vent line from the tank to the PRV inlet is not to exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 4.5.3.1 of this Section;

② pilot-operated PRVs are to be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and

③ pressure losses in remotely sensed pilot lines are to be considered for flowing type pilots.

(3) Downstream pressure losses

① where common vent headers and vent masts are fitted, calculations are to include flow from all attached PRVs;

② the built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, is not to exceed the following values:

(a) for unbalanced PRVs: 10% of MARVS;

(b) for balanced PRVs: 30% of MARVS;

(c) for pilot operated PRVs: 50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

(4) To ensure stable PRV operation, the blow-down is not to be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.

Section 6 LOADING LIMIT FOR FUEL TANKS

4.6.1 General requirements

4.6.1.1 The tank loading limit at an actual loading temperature is not to exceed that obtained from the following formula:

$$LL = FL \rho_R / \rho_L$$

where:

LL—— loading limit as defined in 1.1.2.31, expressed in per cent;

FL—— filling limit as defined in 1.1.2.18, expressed in per cent, here 98%;

ρ_R—— relative density of fuel at the reference temperature; and

ρ_L—— relative density of fuel at the loading temperature.

4.6.1.2 In cases where the tank insulation and tank location make the probability very small① for the tank contents to be heated up due to an external fire, special considerations may be made by CCS to allow a higher loading limit than calculated using the reference temperature, but never above 95%.

4.6.1.3 The alternative loading limit option given under 4.6.1.2 of this Section is understood to be an alternative to 4.6.1.1 and only applies in cases where the calculated loading limit using the formulae in 4.6.1.1 gives a lower value than 95%.

Section 7 MAINTAINING OF FUEL STORAGE CONDITION

4.7.1 Control of tank pressure and temperature

4.7.1.1 With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, fuel tank pressure and temperature are to be maintained at all times within their design range by means acceptable to CCS, e.g. by one of the following methods:

(1) reliquefaction of vapours;

(2) thermal oxidation of vapours;

(3) pressure accumulation; or

(4) liquefied gas fuel cooling.

The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition, i.e. only power for domestic load is generated.

4.7.1.2 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.

4.7.1.3 Fuel tank pressure and temperature are to be controlled and maintained within the design range at all times including after activation of the safety system required in 12.1.2.1(2) of the Rules for a period required in 4.7.1.1 of this Section. The activation of the safety system alone is not deemed as an emergency situation.

4.7.2 Design of systems

4.7.2.1 For worldwide service, the upper ambient design temperature is to be sea 32°C and air 45°C. For service in particularly hot or cold zones, these design temperatures are to be increased or decreased, to

① May be demonstrated by risk assessment.

the approval of CCS.

4.7.2.2 The overall capacity of the system is to be such that it can control the pressure within the design conditions without venting to atmosphere.

4.7.3 Reliquefaction systems

4.7.3.1 The reliquefaction system is to be designed and calculated according to 4.7.3.2 of this Section. The system is to be sized in a sufficient way also in case of no or low consumption.

4.7.3.2 The reliquefaction system is to be arranged in one of the following ways:

(1) a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;

(2) an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

(3) a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks.

4.7.3.3 If the reliquefaction system produces a waste stream containing methane during pressure control operation within the design conditions, these waste gases are, as far as reasonably practicable, to be disposed of without venting to atmosphere.

4.7.4 Thermal oxidation systems

4.7.4.1 Thermal oxidation can be done by either consumption of the vapours according to the requirements for consumers described in the Rules or in a dedicated gas combustion unit (GCU). It is to be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard, periods of slow steaming and/or no consumption from propulsion or other services of the ship are to be considered.

4.7.5 Compatibility

4.7.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel are to be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these are to be compatible with each other.

4.7.6 Availability of systems

4.7.6.1 The availability of the system and its supporting auxiliary services are to be such that in case of a single failure (of mechanical non-static component or a component of the control systems), the fuel tank pressure and temperature can be maintained by another service/system.

4.7.6.2 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges are to have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

Section 8 ATMOSPHERIC CONTROL WITHIN FUEL CONTAINMENT SYSTEMS

4.8.1 General requirements

4.8.1.1 A piping system is to be provided to enable each fuel tank to be safely gas-freed and purged and to be safely filled with fuel from a gas-free condition. The system is to be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

4.8.1.2 The system is to be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

4.8.1.3 Gas sampling points are to be provided for each fuel tank to monitor the progress of atmosphere change.

4.8.1.4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

4.8.2 Atmosphere control within fuel storage hold spaces (fuel containment systems other than type C independent tanks)

4.8.2.1 Interbarrier and fuel storage hold spaces associated with fuel containment systems requiring full or partial secondary barriers are to be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which is to be sufficient for normal consumption for at least 30 days.

4.8.2.2 Alternatively, the spaces referred to in 4.8.2.1 of this Section requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand is to be provided.

4.8.3 Atmosphere control within spaces surrounding type C independent tanks

4.8.3.1 Fuel storage hold spaces are to be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This is only applicable to liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue.

Section 9 INERTING

4.9.1 General requirements

4.9.1.1 Arrangements to prevent back-flow of fuel vapour into the inert gas system are to be provided as specified below.

4.9.1.2 To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line is to be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve is to be installed between the double block and bleed arrangement and the fuel system. These valves are to be located outside non-hazardous spaces.

4.9.1.3 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in 4.9.1.2 of this Section.

4.9.1.4 The arrangements are to be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. are to be provided for controlling pressure in these spaces.

4.9.1.5 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means are to be provided to monitor the quantity of gas being supplied to individual spaces.

4.9.1.6 For fuel storage hold spaces on a passenger ship which are protected by inerting gas, warning and suitable means are to be provided to limit passengers to entering these spaces. If the accesses of these spaces are not from the open deck, enclosed means are to be provided to prevent inerting gas into the adjacent spaces.

4.9.2 Inert gas production and storage on board

4.9.2.1 The equipment is to be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter is to be fitted to the inert gas supply from the equipment and to be fitted with an alarm set at a maximum of 5% oxygen content by volume.

4.9.2.2 An inert gas system is to have pressure controls and monitoring arrangements appropriate to the fuel containment system.

4.9.2.3 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment is to be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm is to be fitted.

4.9.2.4 Nitrogen pipes are only to be led through well ventilated spaces. Nitrogen pipes in enclosed spaces are to:

(1) be fully welded;

(2) have only a minimum of flange connections as needed for fitting of valves; and

(3) be as short as possible.

Section 10 DIRECT CALCULATION OF STRUCTURAL STRENGTH

4.10.1 General requirements

4.10.1.1 Finite element analysis is to be carried out to assess the strength of the hull structures and support structures of the tanks and within the tank areas. The load and stress criterion for the tank structure is to comply with Section 2 of this Chapter, as appropriate.

4.10.1.2 Tank scantlings are to comply with CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk or Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk, as applicable.

4.10.1.3 Stress analysis may be carried out for the tank and its overall attached structures provided that it is subjected to a complex stress condition due to its arrangement[①].

① E.g., a connection of tank connection spaces to spaces containing bolted hatch and airlocks, or a tank provided with two

4.10.1.4 For sea-going ships, the strength of hull structure and its supporting in tanks and tank areas is also to be assessed according to Annex 3 Strength Assessment of Fuel Tank Structures of Sea-going Ships of the Rules, if appropriate.

4.10.1.5 For inland waterways ships, the strength of hull structure and its supporting in tanks and tank areas is also to be assessed according to Annex 4 Strength Assessment of Fuel Tank Structures of Inland Waterways Ships of the Rules, if appropriate.

tank connection spaces.

CHAPTER 5　GAS FUEL BUNKERING

Section 1　GENERAL PROVISIONS

5.1.1 Goal

5.1.1.1 The goal of this Chapter is to provide for suitable systems on board the ship to ensure that bunkering operation can be conducted without causing danger to personnel, the environment or the ship.

5.1.2 Functional requirements

5.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1) to (11) and (13) to (17) of the Rules. In particular the following apply:

（1）The piping system for transfer of fuel to the storage tank is to be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

5.1.3 General requirements

5.1.3.1 Portable means of communication is to be provided from the bunkering source to the ship, such as suitable number of portable VHF-radiotelephones with a explosion-proof grade appropriate to the operational environment.

Section 2　BUNKERING STATIONS

5.2.1 General requirements

5.2.1.1 Bunkering stations are to be located on open deck so that sufficient natural ventilation is provided. Enclosed or semi-enclosed bunkering stations are to be subject to special consideration within the risk assessment, and the assessment report is to be approved by CCS.

The special consideration is as a minimum to include, but not be restricted to, the following design features:

（1）segregation towards other areas on the ship;

（2）hazardous area arrangement on the ship;

（3）requirements for forced ventilation;

（4）requirements for leakage detection (e.g. gas and low temperature detection);

（5）safety actions related to leakage detection (e.g. gas and low temperature detection);

（6）access to bunkering station from non-hazardous area through airlock;

（7）monitoring of bunkering station by direct line of sight or by a closed circuit television (CCTV).

5.2.1.2 Connections and piping are to be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.

5.2.1.3 Arrangements are to be made for safe management of any spilled fuel.

5.2.1.4 Drip trays are to be fitted at the LNG bunkering connections and any location where leakage of liquefied gas may occur. Means are to be provided to the drip tray to safely handle the leakage, such as a pipe that preferably leads down near the water through which LNG will be drained over the ship's side. Drip trays are to comply with 2.3.7 of the Rules.

5.2.1.5 Suitable means are to be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines. Liquid is to be discharged to the liquefied gas fuel tanks or other suitable location.

5.2.1.6 The surrounding hull or deck structures are not to be exposed to unacceptable cooling, in case of leakage of fuel.

5.2.1.7 For LNG bunkering, means are to be provided to prevent the surrounding hull or deck structures from unacceptable cooling in case of leakage, such as a water curtain or shielding.

5.2.1.8 For CNG bunkering stations, low temperature steel shielding is to be considered to determine if the escape of cold jets impinging on surrounding hull structure is possible.

5.2.2 Ship's fuel hoses

5.2.2.1 Liquid and vapour hoses used for fuel transfer are to be compatible with the fuel and suitable for the fuel temperature.

5.2.2.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, are to be designed for a bursting pressure not less than five times the maximum pressure the hose may be subjected to during bunkering.

5.2.3 Bunkering manifolds

5.2.3.1 Bunkering manifolds are to be designed to withstand the external loads during bunkering. The connections at the bunkering station are to be of dry-disconnect type equipped with additional safety dry break-away coupling/self-sealing quick release. The couplings are to be of a standard type.

5.2.3.2 The connections at the bunkering station are to be arranged in order to achieve a dry-disconnect operation in one of the followings ways:

（1）Quick disconnecting couplings (QC/DC).The design, manufacture and testing of a QC/DC are to comply with the standards① accepted by CCS; or

（2）Manual or hydraulic driving couplings. The couplings are generally fitted at the ends of loading arm for connecting the bunkering system to the pipe flange of the bunkering manifold of the receiving ship. The design, manufacture and testing of the couplings and loading arms are to comply with the standards② accepted by CCS; or

（3）Combinations of bolted flange and flange assembly. The flange sizing is to comply with the standards③ accepted by CCS.

In cases when the couplings mentioned in (2) and (3) above are used, an operational procedure for achieving dry disconnection is to be combined. In addition, the bunkering arrangement is to be subject to

---

① E.g. GB/T 39038 Ship and marine technology—Technical requirements for liquefied natural gas bunkering dry-disconnect/connect coupling and ISO 21593 Ships and marine technology — Technical requirements for dry disconnect/connect couplings for bunkering liquefied natural gas.

② E.g. HG/T 21608 Engineering technical requirements for liquid loading arm, ISO 20519 Ships and marine technology — Specification for bunkering of liquefied natural gas fueled vessels, OCIMF Design and Construction Specification for Marine Loading Arms and ISO 16904 Petroleum and natural gas industries--Design and testing of LNG marine transfer arms for conventional onshore terminals etc.

③ E.g. HG/T 20592-20635 Steel Pipe Flanges, Gaskets and Bolting, CLASS series, PN designated, D150 and above specified in ASME B16.5 Pipe Flanges & Flanged Fittings and ISO 20519 Ships and marine technology — Specification for bunkering of liquefied natural gas fueled vessels etc.

special consideration within the risk assessment, including the effects due to dynamic loads at the bunkering connections, safety operation and other risks related to the ship during bunkering.

Section 3 BUNKERING SYSTEMS

5.3.1 General requirements

5.3.1.1 An arrangement for purging fuel bunkering lines with inert gas is to be provided.

5.3.1.2 The bunkering system is to be arranged that no LNG gas is discharged to the atmosphere during bunkering.

5.3.1.3 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve is to be fitted in every bunkering line close to the connecting point. It is to be possible to operate the remote valve in the control location for bunkering operation and/or from another safe location.

5.3.1.4 Means are to be provided for draining any fuel from bunkering pipes upon completion of bunkering operation.

5.3.1.5 Bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes are to be free of gas, unless the consequences of not gas freeing is evaluated and approved by CCS.

5.3.1.6 In case bunkering lines are arranged with a cross-over, it is to be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

5.3.1.7 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source is to be fitted for sea-going ships.

5.3.1.8 If it is not demonstrated that a higher value is required due to pressure surge considerations, a default time as calculated in accordance with 13.7.3.8 of the Rules from the trigger of the alarm to full closure of the remote operated valve required by 5.3.1.3 of this Section is to be adjusted.

5.3.1.9 A filter device is to be provided to the bunkering manifold, and its connection to the fuel source is to comply with 3.2.1.3 .

5.3.1.10 Where a bunkering pipe passes through an enclosed space, it is to be enclosed in the venting duct, and the venting duct is to be arranged in accordance with the requirements for gas supply piping ducts in the Rules. Ventilation and gas detection are to be persistent during bunkering. In case of loss of ventilation or on detection of flammable gas in ventilated ducts, an audible and visual alarm is to be given at the bunkering control location.

CHAPTER 6 FUEL SUPPLY TO CONSUMERS

Section 1 GENERAL PROVISIONS

6.1.1 Goal

6.1.1.1 The goal of this Chapter is to ensure safe and reliable distribution of fuel to the consumers.

6.1.2 Functional requirements

6.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1) to (6), (8) to (11) and (13) to (17) of the Rules. In particular the following apply:

(1) The fuel supply system is to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspections;

(2) The piping system for fuel transfer to the consumers is to be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

Two independent safety barriers are to be provided for satisfying 3.2.6.3, 6.1.2.1 (2) and 6.4.1.1 of the Rules, combined with the use of minimum flange connections as far as practicable. A single common flange or other component are not to be used because its own single fault may destroy the primary and secondary barrier protection and may lead to gas leakage into the surrounding areas which cause harm to persons on board, the environment or the ship. A single common flange with two sealing systems may be accepted to the connection of fuel pipe to gas consumer, including gas combustion units, boilers and components of engine, e.g. gas regulators.

(3) Fuel lines outside the machinery spaces are to be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

6.1.3 General requirements

6.1.3.1 For single fuel installations, the fuel supply system is to be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power.

6.1.3.2 For single fuel installations, the fuel storage is to be divided between two or more tanks. The tanks are to be located in separate compartments.

6.1.3.3 For single fuel installations, two or more fuel tanks, if located on weather deck, are to be as far apart as practicable for preventing a fire in one tank affecting normal operation of other tanks.

6.1.3.4 For single fuel installations, one tank may be accepted if two completely separate tank connection spaces are installed for one type C independent tank.

6.1.3.5 For single fuel installations, they may be located in one compartment provided that two or more type C independent tanks are fitted and each is fitted with a separate tank connection space.

6.1.3.6 Warning signs

(1) When gas supply is shutoff due to the action of automatic stop valve, it is not to be resumed unless the causes are found out and the corresponding measures are adopted. A corresponding warning sign is to be posted in a conspicuous place of the gas supply piping control room.

(2) When gas supply is shutoff due to the leakage of gas fuel, it is not to be resumed unless the leakage source is found out and the corresponding measures are adopted. A corresponding warning sign is to be posted in a conspicuous place of the gas supply piping control room;

(3) Any operation which may damage the gas supply pipes is not permitted when the engine runs. A corresponding warning sign is to be posted in a conspicuous place of the gas engine room.

6.1.3.7 For passenger ships required to meet the requirements for safe return to port, the gas supply systems or oil supply systems to the same power system are to be independent, and it is to be ensured that the gas or oil supply to this power system is in order in case of a fire in or flooding of any compartment.

6.1.3.8 An arrangement for purging fuel supply lines with inert gas is to be provided.

Section 2 ARRANGEMENT OF GAS SUPPLY VALVES

6.2.1 General requirements

6.2.1.1 Fuel storage tank inlets and outlets are to be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation① which are not accessible are to be remotely operated. Tank valves, whether accessible or not, are to be automatically operated when the safety system required in Table 12.4.3 of the Rules is activated.

6.2.1.2 A manually operated stop valve and a tank master valve in series, or a combined manually operated and master valve is to be fitted in every gas supply outlet of the tank, and to be located close to the tank as far as possible.

6.2.1.3 The main gas supply line to each gas consumer or set of consumers is to be equipped with a manually operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined manually and automatically operated valve. The master gas fuel valve is to be located outside the machinery space and close to the heater (if any) or heat exchanger as far as practicable.

6.2.1.4 The master gas fuel valve is to automatically cut off the gas supply when activated by the safety system required in Table 12.4.3 of the Rules, and be operable from safe locations on escape routes inside an engine room, the engine control room, if applicable, outside the machinery space and from the navigation bridge.

6.2.1.5 Gas supply pipes leading to each gas engine are to be provided with double block and bleed valves. These valves are to be arranged as follows:

(1) The two shutoff valves are to be in series in the gas fuel pipe to the gas engine, and the third valve is to be in a pipe that vents to a safe location in the open air that portion of the gas fuel pipe that is between the two valves in series. The vent outlet is to be arranged according to 4.5.2.9 of the Rules and may lead to the vent system defined in 4.5.2.7 of the Rules;

(2) A failure mentioned in Table 12.4.3 of the Rules is to cause the shutoff valves that are in series to close automatically and the ventilation valve to open automatically;

(3) The function of one of the two valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the gas supply will be automatically blocked and the ventilation automatically opened in the case of a failure defined in Table 12.4.2 and Table 12.4.3 of the Rules;

(4) The three valves above are to be capable of manual reset;

(5) The two valves in series are to be of the fail-to-close type, while the ventilation valve is to be fail-

① Normal operation in this context is when gas is supplied to consumers and during bunkering operation.

to-open;

(6) Normal stop of the engine is to cause the shutoff valves that are in series to close automatically and the ventilation valve opened automatically.

6.2.1.6 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve is to be automatically ventilated assuming reverse flow from the engine to the pipe.

6.2.1.7 For gas engines with an injection pressure of more than 1 MPa, automatic shutoff of the master gas fuel valve is to cause the gas supply pipes between the valve and the double block and bleed valve and between the double block and bleed valve and the engine injection valve to be automatically ventilate.

6.2.1.8 There is to be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to ensure safe isolation during maintenance on the engine.

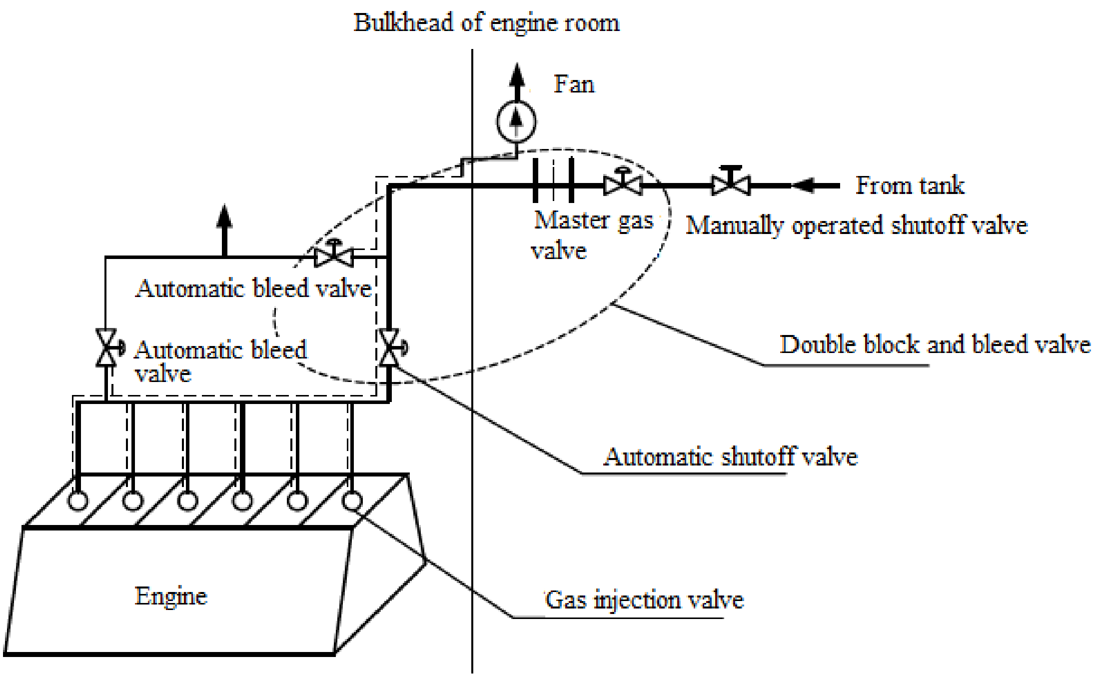
6.2.1.9 Where a separate master valve is provided for each gas engine, the master gas fuel valve and the double block and bleed valve functions can be combined, that is the master gas fuel valve may be used as one shutoff valve of the double block and bleed valve to shutoff the gas supply. The gas supply valves of single-engine installations and multi-engine installations are arranged as shown in Figure 6.2.19 (a) and Figure 6.2.1.9 (b).

6.2.1.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations, means are to be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected, a valve is to be automatically shut off[①]. This valve is to be located in the gas supply line before it enters the engine-room or as close as possible to the point of entry inside the engine-room. It can be a separate valve or combined with other functions, e.g. the master valve. Means of detection accepted by CCS include, but are not limited to:

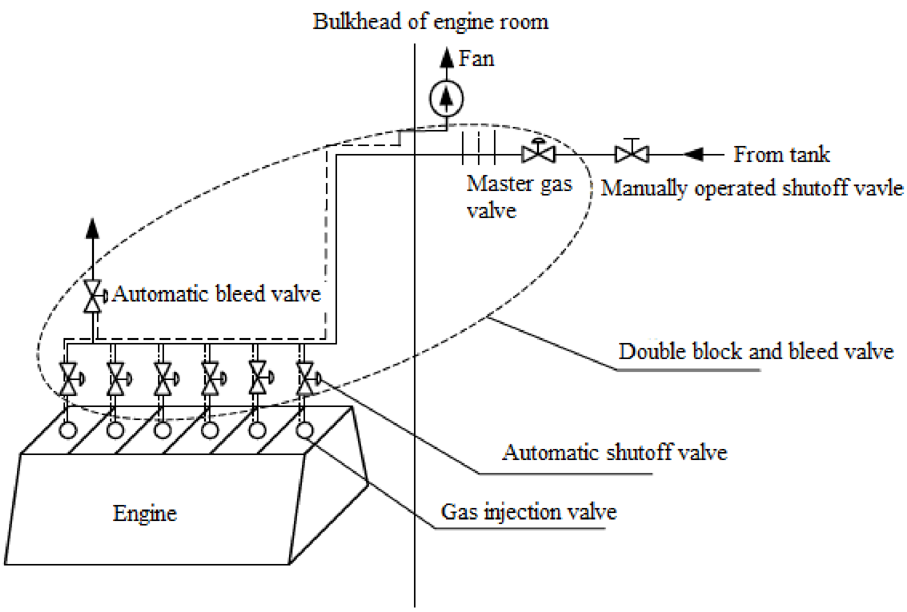
(1) a combined excess flow detector with automatic stop valve located on the gas supply line close to the point of entry to the engine room; or

(2) a low pressure detector located at the gas engine inlet.

① The shutdown is to be time delayed to prevent shutdown due to transient load variations.

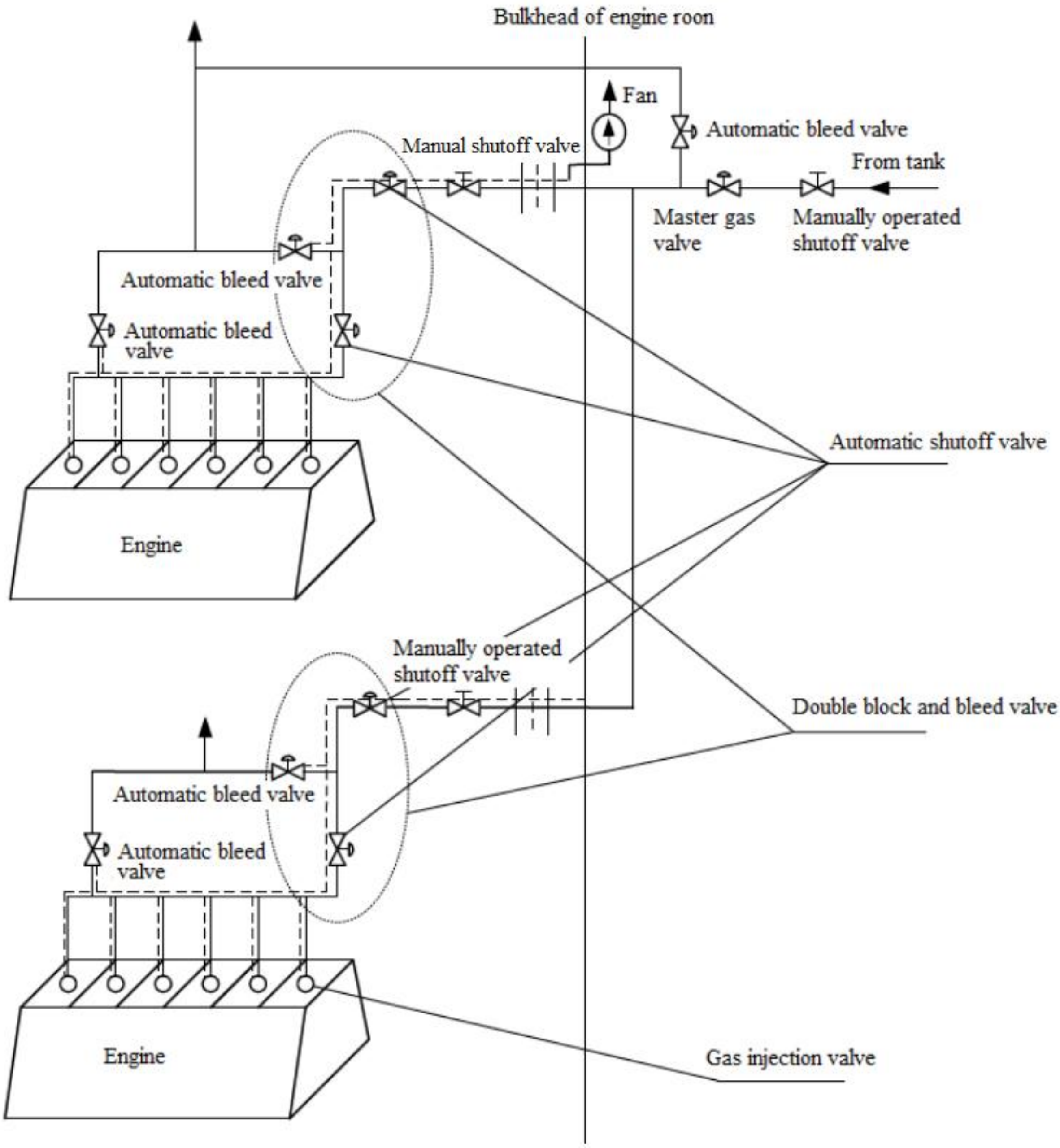


Arrangement ①

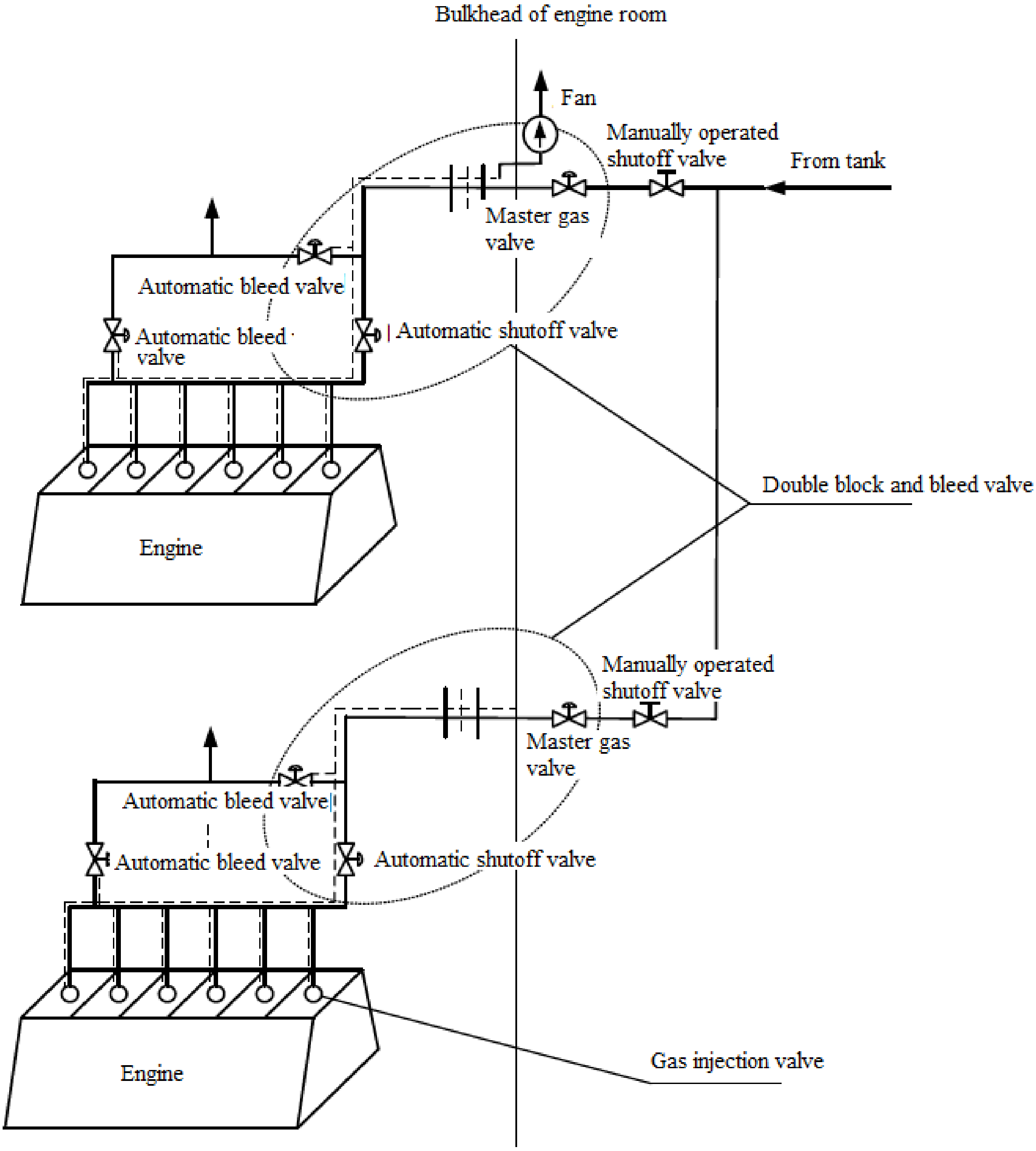


Arrangement ②

Figure 6.2.1.9 (a) The Example of Arrangement of Gas Supply Valves of Single-engine Systems



Arrangement ①



Arrangement ②

Figure 6.2.1.9 (b) The Example of Arrangement of Gas Supply Valves of Multi-engine Systems

Section 3 GAS SUPPLY SYSTEMS OUTSIDE OF MACHINERY SPACES

6.3.1 General requirements

6.3.1.1 Where fuel pipes pass through enclosed spaces other than those referred to in 2.3.4.2 of the

Rules, they are to be of double wall. Such double wall pipes are to be mechanically underpressure ventilated with 30 air changes per hour, and provided with gas detection as required in 12.3.1 of the Rules. Alternatives providing an equivalent safety level may also be accepted by CCS.

6.3.1.2 The requirement in 6.3.1.1 of this Section need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

6.3.1.3 Pipes containing LNG liquid are to be protected by a secondary enclosure able to contain liquid leakage. If the piping system is situated in a fuel preparation room or a tank connection space, CCS may waive this requirement. Where gas detection as required in 12.3.1.1(2) of the Rules is not fit for purpose, the secondary enclosures around liquefied fuel pipes are to be provided with leakage detection by means of pressure or temperature monitoring systems, or any combination thereof. The secondary enclosure is to be able to withstand the maximum pressure that may build up in the enclosure in case of leakage from the fuel piping. For this purpose, the secondary enclosure may need to be arranged with a pressure relief system that prevents the enclosure from being subjected to pressures above their design pressures.

6.3.1.4 The design pressure of double wall pipe in enclosed space is to comply with 6.4.1.3 and 6.4.1.4 of this Chapter.

6.3.1.5 A high pressure gas supply line installed outside of engine room is to be protected to minimize the risk of injury to personnel in case of rupture.

6.3.1.6 Gas supply lines are not to pass through special category spaces, ro-ro spaces and vehicle spaces. If this is impracticable, they are to be double wall piping, and effective means are to be provided to protect the piping from damage due to vehicle collision.

6.3.1.7 For ships carrying dangerous chemicals in bulk, the gas supply lines are not to pass through tanks and cargo pump-rooms.

6.3.2 Fuel heating

6.3.2.1 The temperature at the outlet of the heat exchanger is to be monitored. In case of a low temperature, an audible and visual alarm is to be given in the navigation bridge or at a manned location of the engine room, and the LNG transfer pump (if fitted) is to be automatically shutdown and the tank master valve is to be shutoff.

6.3.2.2 The circuit in which the primary heating medium is contained is to be fitted with an expansion tank or other means which would be equally effective. An expansion tank, if fitted, is to be provided with:

（1）a liquid meter, temperature gauge and vent pipe;

（2）a high and low liquid level alarm;

（3）a means detecting flammable gas in the top of vapour space;

（4）vents, in the case of gas heating circuit expansion tank, leading to an open area.

6.3.2.3 For ships carrying dangerous chemicals in bulk, the gas heating circuit is to be independent from that of the tank.

6.3.2.4 Effective means are to be provided to prevent fuel from leaking to the machinery space via the heating medium.

Section 4 GAS SUPPLY SYSTEMS IN MACHINERY SPACES

6.4.1 Gas supply systems in gas-safe machinery spaces

6.4.1.1 Gas supply piping in gas safe machinery spaces is to be double wall piping fulfilling one of the following conditions:

(1) The gas piping is to be a concentric pipe made up by an inner pipe and an outer pipe with the gas fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the concentric pipes. When the inner pipe contains high pressure gas, the system is to be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed.

(2) The gas fuel piping is to be installed within a ventilated duct. The air space between the gas fuel piping and the ventilated duct is to be provided equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors are to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

6.4.1.2 The connecting of gas supply piping to the gas injection valves is to be completely covered by the ducting, and the arrangement is to facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber. However,

(1) Where gas is directly injected to the air inlet branch or air intake of each cylinder at a low pressure, double wall piping may be dispensed with to the air inlet pipe of the engine; or

(2) For ships engaged on domestic voyages, double wall piping may be dispensed with to the air inlet pipe of the engine, provided that fuel is injected downstream of the turbocharger to the air inlet manifold of the engine at a low pressure and at least one gas detector is fitted above the engine.

6.4.1.3 The design pressure of the outer pipe or duct of fuel systems is not to be less than the maximum working pressure of the inner pipe. Alternatively, for high-pressure fuel piping the design pressure of the ducting is to be taken as the higher of the following:

(1) the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

(2) local instantaneous peak pressure in way of the rupture p^*, given by the following expression:

$$p^* = p_0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where, p_0—— maximum working pressure of the inner pipe;

k—— constant pressure specific heat divided by the constant volume specific heat, $k = 1.31$ for CH_4;

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1.5(R_m/1.5) when subjected to the above pressures. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes. As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports are then to be submitted.

6.4.1.4 Verification of the strength is to be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

6.4.2 Gas supply systems in ESD protected machinery spaces

6.4.2.1 The pressure in the gas fuel supply system is not to exceed 1.0 MPa.

6.4.2.2 The gas fuel supply lines are to have a design pressure not less than 1.0 MPa.

Section 5 COMPRESSORS AND PUMPS

6.5.1 General requirements

6.5.1.1 If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration is to be of gastight type.

6.5.1.2 Compressors and pumps are to be suitable for their intended purpose. All equipment and machinery are to be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered are to include, but not be limited to:

(1) environmental factor;

(2) shipboard vibrations and accelerations;

(3) effects of pitch, heave and roll motions, etc.; and

(4) gas composition.

6.5.1.3 Arrangements are to be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

6.5.1.4 Compressors and pumps are to be fitted with accessories and instrumentation necessary for efficient and reliable operation.

CHAPTER 7 GAS CONSUMERS

Section 1 GENERAL PROVISIONS

7.1.1 Goal

7.1.1.1 The goal of this Chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

7.1.2 Functional requirements

7.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1), (11), (13) and (16) to (17) of the Rules. In particular the following apply:

(1) The exhaust systems are to be configured to prevent any accumulation of un-burnt gaseous fuel;

(2) Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture are to be fitted with suitable pressure relief systems. Dependent on the particular engine design, this may include the air inlet manifolds and scavenge spaces;

(3) The explosion venting is to be led away from where personnel may normally be present;

(4) All gas consumers are to have a separate exhaust system.

7.1.3 General requirements

7.1.3.1 Gas engines are to comply with Chapter 7 and Chapter 12 of the Rules, Appendix 1, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, as well as other applicable requirements of CCS Rules,as appropriate, and are to have a marine products certificate.

7.1.3.2 For gas engines with electronic control systems, the electronic control systems are to comply with Annex 5 of the Rules.

7.1.3.3 Engine manufacturers are to indicate the extent of variations of methane content and low heat values appropriate to the gas engine.

7.1.3.4 Risk analysis is to be conducted on all possible faults likely affecting the safe operation of engine to determine the items necessary for monitoring the engine, and the analysis report is to be submitted to CCS. The risk analysis is to comply with Appendix 1, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.1.3.5 For engines starting on gas fuels, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply unit, the fuel supply unit is to be automatically shut off, and means are to be provided to ensure that any unburnt fuel mixture is purged away from the exhaust system.

Section 2 INTERNAL COMBUSTION ENGINES OF PISTON TYPE

7.2.1 General requirements

7.2.1.1 Where compressed air is introduced directly into the cylinder for starting purposes, a flame arrester is to be fitted on each starting air branch for direct reversing engines, or on starting air manifolds for non-reversing engines.

7.2.1.2 Premixed engines where the gas fuel is mixed with air at the upstream of turbocharger are to be arranged in an ESD protected machinery space.

7.2.1.3 The engine air intakes, if located inside the engine room, are to be situated as far apart as practicable from the gas supply pipe to reduce the risk of the leakage gas entering the intake; and if located outside the engine room, they are to be at least 1.5 m away from the boundaries of any hazardous area.

7.2.1.4 Where gas fuel is introduced into the cylinder through the intake manifold, an explosion relief valve or explosion-proof means is to be fitted on the intake manifold, unless documentation demonstrates that the system has sufficient strength to contain the worst-case explosion. In addition, where gas fuel is mixed with air at the upstream of turbocharger, an explosion relief valve is to be fitted on the turbocharger or intercooler, unless documentation demonstrates that the turbocharger or intercooler has sufficient strength to contain the worst-case explosion.

7.2.1.5 Crankcases are to be provided with relief valves according to 9.7.4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.2.1.6 For engines where the space below the piston is in direct communication with the crankcase, a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out.

Where it cannot be demonstrated that gas detection in the crankcase exceeds LEL in no circumstances, the following apply:

(1) An oil mist detector (e.g. bearing temperature detector) or equivalent device is to be fitted in the crankcase to monitor the heat points;

(2) Electrical installation and instruments in the crankcase, including oil mist detectors, are to be of the certified safe type.

7.2.1.7 Each engine other than two-stroke crosshead diesel engines is to be fitted with vent systems independent of other engines for crankcases.

The vent pipes are to be fitted with flame arresters or equivalent devices, and the vents are to be led to a safe location in open area or a location of safe handling of gas. The crankcases are to be provided with an interface or other means for inerting to to allow for maintenance service.

7.2.1.8 The exhaust system is to be equipped with explosion relief systems unless it is designed to accommodate the overpressure due to ignited gas leaks or the worst-case overpressure shown in the safety concept of the engine. A detailed evaluation of the potential for unburnt gas in the exhaust system is to be undertaken, covering the complete system from the cylinders up to the open end. This detailed evaluation is to be reflected in the safety concept of the engine.

7.2.1.9 The relief valves required in 7.2.1.8 of this Section may be dispensed with if documentation demonstrates that the exhaust pipe has sufficient strength to contain the worst-case explosion.

7.2.1.10 Means are to be provided to purge the potential combustible gas in exhaust pipes after the stop of engine in gas mode.

7.2.1.11 If the dismantling or replacement of explosion relief valves required after their actions will affect the continuous running of engine, they are not to be installed on the main propulsion installations of single engine, unless an auxiliary propulsion system is provided.

7.2.1.12 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means is to be fitted after the engine outlet to extract gas in order to prevent gas dispersion.

The gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere.

7.2.1.13 A means is to be provided to monitor and detect poor combustion or misfiring in the engine. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations.

7.2.2 Dual fuel engines

7.2.2.1 In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only without interruption.

7.2.2.2 Only oil fuel is to be used for engines at start, normal stop, idle running, low-load operation, high-load operation and overload operation, unless documentation demonstrates that the engine is capable of safe starting and normal stopping in gas fuel mode, and of safe running in the idle, low-load, high-load and overload conditions.

7.2.2.3 An automatic system is to be fitted to the engine to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum fluctuation of the engine power. Acceptable reliability is to be demonstrated through testing. In the case of unstable operation on engines when ammonia firing, the engine is to automatically change to oil fuel mode. Manual activation of gas system shutdown is always to be possible.

7.2.2.4 In case of a normal stop or an emergency shutdown, the gas fuel supply is to be shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

7.2.2.5 Firing of the gas-air mixture in cylinders is to be initiated by pilot fuel. The amount of pilot fuel injected to each cylinder is to be sufficient to ensure a positive ignition of the gas mixture.

7.2.3 Gas-only engines

7.2.3.1 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit is to be verified.

7.2.3.2 The gas fuel supply system is to ensure that sufficient gas is provided for initial start of the engine.

7.2.3.3 Starting of ignition system is not to be possible until the engine reaches the minimum ignition speed, and the gas supply unit may be permitted to operate only after the ignition.

7.2.3.4 A means is to be provided to purge the unburnt combustible mixture in the exhaust pipe after a failed start of engine. Restarting is not to be possible before the exhaust pipe has been completely purged.

7.2.3.5 In case of a normal stop or an emergency shutdown, the gas fuel supply is to be shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

7.2.3.6 For constant speed engines, the gas supply unit is to be shut off in idle condition, and the ignition system is to continuously operate till the stop of engine.

Section 3 MAIN AND AUXILIARY BOILERS

7.3.1 General requirements

7.3.1.1 Each boiler is to have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use provided that any relevant safety functions are maintained.

7.3.1.2 Combustion chambers and uptakes of boilers are to be designed to prevent any accumulation of gas fuel.

7.3.1.3 Burners are to be designed to maintain stable combustion under all firing conditions.

7.3.1.4 On main/propulsion boilers, an automatic system is to be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

7.3.1.5 Gas nozzles and the burner control system are to be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by CCS to light on gas fuel.

7.3.1.6 There are to be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

7.3.1.7 On the fuel pipe of each gas burner, a manually operated shutoff valve is to be fitted.

7.3.1.8 Provisions are to be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

7.3.1.9 The automatic fuel changeover system required by 7.3.1.4 of this Section is to be monitored with alarms to ensure continuous availability.

7.3.1.10 Arrangements are to be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

7.3.1.11 Arrangements are to be made to enable the boilers purging sequence to be manually activated.

Section 4 GAS TURBINES

7.4.1 General requirements

7.4.1.1 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, the exhaust systems are to be fitted with suitable pressure relief systems. The exhaust outlets are to lead to a safe location away from personnel.

7.4.1.2 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 2.3.3 and 6.4.2 of the Rules, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.

7.4.1.3 Gas detection systems and shutdown functions are to be as outlined for ESD protected machinery spaces.

7.4.1.4 Ventilation for the enclosure is to be as outlined in Chapter 10 of the Rules for ESD protected machinery spaces, but is in addition to be arranged with full redundancy (2 × 100% capacity fans from different electrical circuits).

7.4.1.5 For other than gas-only turbines, an automatic system is to be fitted to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum fluctuation of the engine power.

7.4.1.6 Means are to be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the gas fuel supply is to be shutdown.

7.4.1.7 Each turbine is to be fitted with an automatic shutdown device for high exhaust temperatures.

CHAPTER 8 FIRE SAFETY

Section 1 GENERAL PROVISIONS

8.1.1 Goal

8.1.1.1 The goal of this Chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of natural gas as ship fuel.

8.1.2 Functional requirements

8.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (2), (4), (5), (7), (12), (14), (15) and (17) of the Rules.

Section 2 FIRE PROTECTION

8.2.1 General requirements

8.2.1.1 Any space containing equipment for the fuel preparation, such as pumps, compressors, heat exchangers, vaporizers and pressure vessels, is to be regarded as a machinery space of category A/an essential machinery space for fire protection purposes. Where, fire protection refers to having structural fire protection, exclusive of means of escape.

8.2.1.2 The fire protection of fuel piping led through ro-ro spaces is to be subject to special consideration by CCS depending on the use and expected pressure therein.

8.2.2 Fuel tanks

8.2.2.1 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, is to be shielded by A-60 class divisions. These class divisions are to extend up to the underside of the deck of the navigation bridge or up to the true height of the bulkhead. For the purposes of the stowage and segregation requirements of the International Maritime Dangers Goods (IMDG) Code, a fuel tank on the open deck is to be considered a class 2.1 package.

8.2.2.2 The fuel storage hold space is to be separated from the machinery spaces of category A/essential machinery spaces or other rooms with high fire risk. The separation is to be achieved by a cofferdam of at least 900 mm with insulation of A-60 class which is to be on side of the cofferdam within the machinery spaces of category A/essential machinery spaces or other rooms with high fire risk. When determining the insulation of the fuel storage hold space from other spaces with lower fire risks, the fuel storage hold space is to be considered as a machinery space of category A/essential machinery space for fire protection purposes.

The following 'other rooms with high fire risk' is as a minimum to be considered, but not be restricted to:

（1） cargo spaces, except cargo tanks for liquids with flashpoint above 60°C and cargo spaces exempted in accordance with SOLAS regulation II-2/10.7.1.2 or II-2/10.7.1.4; For ships engaged on domestic voyages, except cargo tanks for liquids with flashpoint above 60°C, if cargo is heated up to the temperature that is 15°C below its flash temperature, and except cargo tanks used for ore, coal, grain, unseasoned timber, non-combustible cargoes and cargoes considered by the Administration to constitute a low fire risk and fitted with steel hatches and efficient means for closing all ventilation outlets and other openings to cargo spaces.

（2） vehicle, ro-ro and special category spaces;

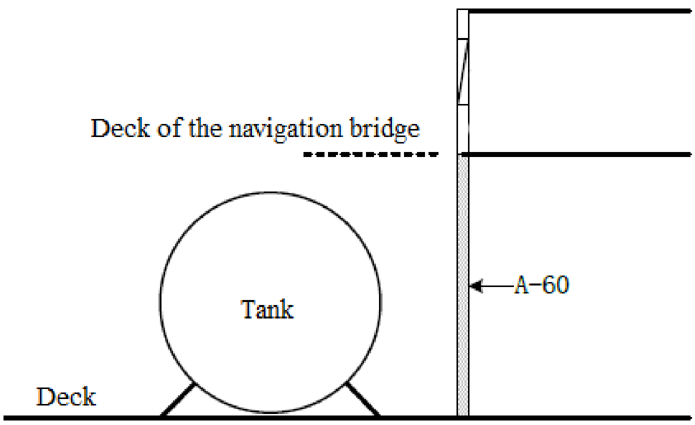
（3） service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m2 or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery spaces, as provided in SOLAS regulations II-2/9.2.2.4, II-2/9.2.3.3 and II-2/9.2.4; For ships engaged on domestic voyages, a space as mentioned above, if provided onboard, is to be considered as a service space (high risk) as provided in this article.

（4） accommodation spaces of greater fire risk: saunas, sale shops, barber shops and beauty parlours and public spaces containing furniture and furnishing of other than restricted fire risk and having a deck area of 50 m2 or more, as provided in SOLAS regulation II-2/9.2.2.3. For ships engaged on domestic voyages, a space as mentioned above, if provided onboard, is to be considered as an accommodation space of greater fire risk

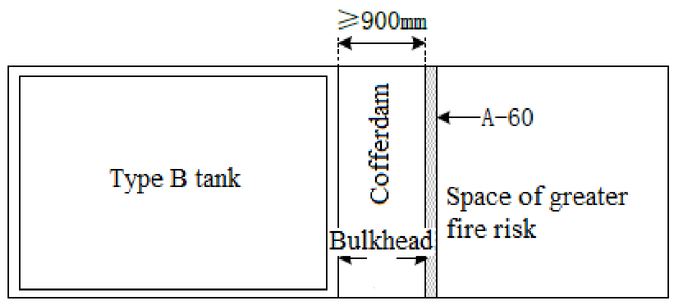
8.2.2.3 For type C independent tanks, the fuel storage hold space may be considered as a cofferdam, provided that the tank outer shell or the boundary of tank connection space, if fitted, is not to be less than 900 mm away from A-60 class divisions, whichever is less. However, where a type C independent tank is directly located above a machinery space of category A/essential machinery space or other spaces of greater fire risk, the separation between the fuel storage hold space or tank and the above spaces is to be achieved by a cofferdam of at least 900 mm with insulation of A-60 class on side of the machinery space of category A/essential machinery space or other spaces of greater fire risk. For inland waterways ships, if this is impracticable, the distance 900 mm may be reduced after assessment, but not less than 500 mm.

8.2.2.4 The fuel storage hold space is not to be used for machinery or equipment that may have a fire risk.

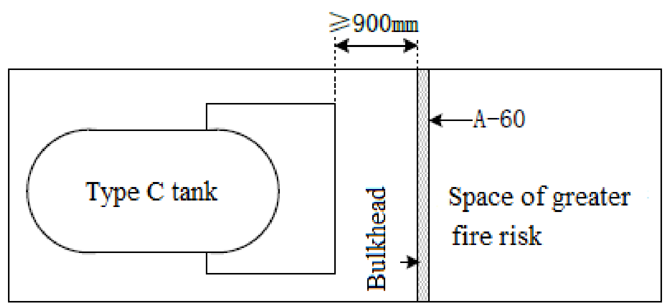
8.2.2.5 The examples for 8.2.2.2 and 8.2.2.3 of this Section are shown in Figure 8.2.2.



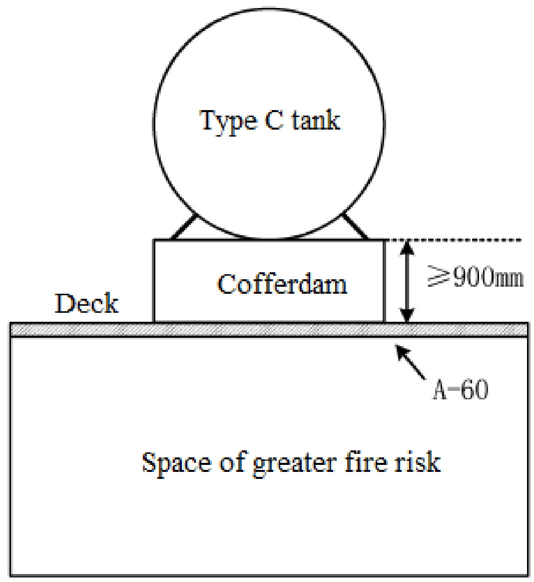
① Tanks arranged on open deck



② Tanks arranged in enclosed space



③ Tanks arranged in enclosed space - Type C independent tanks



④ Tanks arranged above spaces of greater fire risk

Figure 8.2.2 The Example of Tank Fire Divisions

8.2.3 Bunkering stations

8.2.3.1 Any boundary of machinery spaces of category A/essential machinery spaces, accommodation spaces, control stations and spaces of greater fire risk (including other spaces of greater fire risk specified in 8.2.2.2 of this Section), facing the bunkering station, is to be insulated to A-60 class standard. However, the standard may be reduced to A-0 for liquid tanks, voids, auxiliary machinery spaces and sanitaries of minor fire risk as well as other similar spaces.

8.2.3.2 For ships engaged on domestic voyages, where bunkering stations are located on open deck and bunkering connections are more than 10 m far away from the bulkheads of the spaces defined in 8.2.3.1 of this Section, their insulation may be reduced to class A-0. Where the bunkering connections are located at the sunken part of the superstructure or deckhouse, this may be considered as being located on the open deck, provided that the depth of the sunken part does not exceed 1 m. The example of arrangement is shown in Figure 8.2.3.

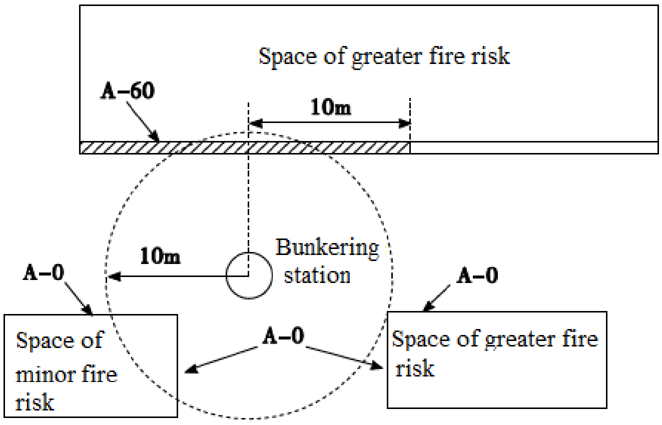


Figure 8.2.3 The Fire Division of Bunkering Station (for ships engaged on domestic voyages)

8.2.4 ESD protected machinery spaces

8.2.4.1 If an ESD protected machinery space is separated by a single boundary, the boundary is to be of A-60 class division.

Section 3 FIRE EXTINGUISHING

8.3.1 General requirements

8.3.1.1 Fuel preparation rooms, gas compressor rooms and gas pump rooms (if fitted) are to comply with the fire extinguishing requirements for cargo compressor rooms and cargo pump rooms of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

8.3.1.2 Enclosed spaces containing fuel preparation arrangements, such as pumps, compressors or other potential ignition sources, are to be provided with a fixed fire-extinguishing system complying with SOLAS II-2/10.4.1.1 and the Fire Safety Systems (FSS) Code or 3.8 of PART FIVE of CCS Technical Regulations for the Statutory Surveys on Inland Waterways Ships, as appropriate, taking into account the concentrations/application rate required for extinguishing gas fires.

8.3.2 Fire main

8.3.2.1 At least two fire pumps are to be provided, of which each has sufficient capacity and pressure to project at least two jets of water with coverage of 12 m at least.

8.3.2.2 The water spray system may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system specified in 8.3.3 of this Section simultaneously.

8.3.2.3 When the fire main is located on the open deck and passes through the tank area thereof, isolating valves are to be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main is not to deprive the fire line ahead of the isolated section from the supply of water.

8.3.2.4 Nozzles are to be of a dual-purpose type (i.e. jet/spray type) incorporating a shutoff.

8.3.3 Water spray systems

8.3.3.1 A water spray system is to be installed for cooling, fire prevention and crew protection to cover exposed parts of fuel storage tank(s) located on open deck.

8.3.3.2 The water spray system is also to provide coverage for boundaries of the superstructures, compressor rooms, pump-rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks unless the tank is located 10 m or more from the boundaries.

8.3.3.3 For inland waterways ships, the water spray system need not provide coverage for the boundaries defined in 8.3.3.2 of this Section if the tank is located 5 m or more from them.

8.3.3.4 The system is to be designed to cover all areas as specified above with an application rate of 10 L/min/m2 for horizontal projected surfaces and 4 L/min/m^2 for vertical surfaces.

8.3.3.5 Stop valves are to be fitted in the water spray application main supply line(s), at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.

8.3.3.6 The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

8.3.3.7 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve is to be provided.

8.3.3.8 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system are to be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

8.3.3.9 The nozzles are to be of an approved type and they are to be arranged to ensure an effective distribution of water throughout the space being protected.

8.3.4 Dry chemical powder fire-extinguishing systems

8.3.4.1 Where the tank is located on open deck, at least two portable dry powder extinguishers of at least 5 kg capacity are to be provided near the tank.

8.3.4.2 Where the LNG fuel tank is located in an enclosed or semi-enclosed space, at least one portable dry powder extinguisher of at least 5 kg capacity is to be provided at the entrance of the fuel storage hold space.

8.3.4.3 A permanently installed dry chemical powder fire-extinguishing system is to be installed in the bunkering station area to cover all possible leak points. The capacity is to be at least 3.5 kg/s for a minimum of 45 s. The system is to be arranged for easy manual release from a safe location outside the protected area.

If this is impracticable for sea-going ships engaged on domestic voyages, they may be provided with a large dry chemical wheeled fire extinguisher having the same capacity.

8.3.4.4 In addition to any portable extinguishers that may be required by the Administration, at least one portable dry powder extinguisher of at least 5 kg capacity is to be located near the bunkering station and in the fuel preparation room respectively.

8.3.4.5 At least one portable dry powder extinguisher of at least 5 kg capacity is to be provided respectively near the gas engine and at the entrance of the machinery space where the engine is located.

Section 4 FIRE DETECTION AND ALARM SYSTEMS

8.4.1 Fire detection

8.4.1.1 A fixed fire detection and fire alarm system complying with the FSS Code is to be provided for the fuel storage hold spaces and the ventilation trunk for fuel containment system below deck, and for all other rooms of the fuel gas system where fire cannot be excluded.

8.4.1.2 Smoke detectors alone are not to be considered sufficient for rapid detection of a fire.

8.4.2 Alarm and safety measures

8.4.2.1 On detection of a fire in the spaces specified in 8.4.1.1 of this Section, safety measures listed in Table 12.4.3 of the Rules are to be applied and ventilation is to be shutoff.

CHAPTER 9 EXPLOSION PREVENTION

Section 1 GENERAL PROVISIONS

9.1.1 Goal

9.1.1.1 The goal of this Chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.

9.1.2 Functional requirements

9.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (2) to (5), (7) to (8), (12) to (14) and (17) of the Rules. In particular the following apply:

The probability of explosions is to be reduced to a minimum by:

(1) reducing the number of sources of ignition;

(2) reducing the probability of formation of ignitable mixtures.

9.1.3 General requirements

9.1.3.1 Hazardous areas on open deck and other spaces not addressed in this Chapter are to be decided based on a recognized standard①. The electrical equipment fitted within hazardous areas is to be according to the same standard.

9.1.3.2 Electrical equipment and wiring are in general not to be installed in hazardous areas unless essential for operational purposes based on recognized standards②.

9.1.3.3 Electrical equipment fitted in an ESD protected machinery space is to fulfill the following:

(1) in addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans are to be certified safe for hazardous area zone 1; and

(2) all electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 is to be automatically disconnected, if gas concentrations above 40% LEL is detected by two detectors in the space containing gas-fuelled consumers.

Section 2 HAZARDOUS AREA CLASSIFICATION

9.2.1 Area classification

9.2.1.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The purpose of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

9.2.1.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2③. See 9.2.2 of this Section.

---

① Refer to IEC 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.
② Refer to IEC standard 60092-502: IEC 60092-502 Electrical Installations in Ships–Tankers–Special Features and IEC 60079-10-1 Explosive atmospheres–Part 10-1: Classification of areas–Explosive gas atmospheres, according to the area classification.
③ Refer to IEC 60079-10-1: Explosive atmosphers Part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features

9.2.1.3 Ventilation ducts are to be the same area classification as the ventilated space.

9.2.1.4 Spaces with entry openings to an adjacent hazardous area may become a safe area by taking the provisions in 2.3.8.1 of the Rules.

9.2.1.5 For gas intake valves at dual fuel engines and gas engines, the following functional requirements apply:

（1）The classification of the valves is to be determined by the risk assessment carried out according to the relevant provisions on area classification as set out in 9.2.1 of this Section.

This assessment is to be taken to mean a procedure equivalent to the examples for hazardous area zones classification as laid out in 9.2.2 of this Section;

（2）The provision of 9.2.1 of this Section is to be understood as a guide for the classification of the valves. In the absence of additional safety measures and no risk assessment is carried out according to 9.2.1, the examples in 9.2.2 of this Section are to apply.

9.2.2 Hazardous area zones

9.2.2.1 Hazardous area zone 0

This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

9.2.2.2 Hazardous area zone 1①

This zone includes, but is not limited to:

(1) tank connection spaces, fuel storage hold spaces② and interbarrier spaces;

(2) fuel preparation rooms arranged with ventilation according to 10.4.1 of the Rules;

(3) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet③, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets, zone 1 ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

(5) areas on the open deck within drip trays for gas bunker manifold valve and 3 m beyond these, up to a height of 2.4 m above the bottom of drip tray;

(6) enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. double walled pipe around fuel pipes, semi-enclosed bunkering stations;

(7) the ESD protected machinery space is considered a non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1;

(8) a space protected by an airlock is considered as non-hazardous area during normal operation, but

for tankers.

① Instrumentation and electrical apparatus installed within these areas are to be of a type suitable for zone 1.

② Fuel storage hold spaces for type C independent tanks are normally not considered as Zone 1. For the purposes of hazardous area classification, they are to be considered non-hazardous provided that they do not lead to any hazardous area and all potential leakage sources of type C tanks are located in the tank connection space. However, if containing potential leakage sources, e.g. tank connections, the spaces are to be considered as Zone 1. And if containing bolted hatch to tank connection space, the spaces are to be considered as Zone 2.

③ Such areas are, for example, all areas within 3 m of fuel tank hatches, ullage openings or sounding pipes for fuel tanks located on open deck and gas vapour outlets.

will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

(9) except for type C independent tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.

9.2.2.3 Hazardous area zone 2[①]

This zone includes, but is not limited to:

(1) areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

(2) spaces containing bolted hatch to tank connection space.

Section 3 ELECTRICAL INSTALLATIONS AND CABLES WITHIN HAZARDOUS AREA

9.3.1 Choice of arrangement of electrical installations in the hazardous area

9.3.1.1 The explosion group and temperature class of explosion proof equipment used for an explosive gas atmosphere which may contain natural gas are not to be lower than IIA T2. The following equipment is allowed to be installed in hazardous zones:

(1) In Zone 0

a) certified intrinsically-safe apparatus of category 'ia';

b) 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 60079-14;

Note: Consideration may need to be given to matters such as the integrity of the insulation from earth of the circuit, the suitability of any plastics or light metals incorporated in the construction of the apparatus or component, and the maximum surface temperature of any part of the apparatus (except in the cases of switches, plugs and sockets, and terminals). Apparatus reliant upon voltage or current limiting or suppression devices for remaining within the limits set by IEC 60079-14, is excluded from the category of 'simple apparatus';

c) other electrical apparatus specifically designed and certified by the Administration for use in zone 0;

d) submersible electrically-driven pumps, having at least two independent methods of shutting down automatically in the event of low liquid level. The construction and installation of the pumps and associated cabling and other means adopted can operate without electricity when not submerged or in an explosive gas atmosphere.

(2) In Zone 1

a) equipment which is allowed to be installed in Zone 0;

b) certified intrinsically-safe apparatus of category 'ib';

① Instrumentation and electrical apparatus installed within these areas are to be of a type suitable for zone 2.

c) 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 60079-14;

d) certified flameproof (type 'd');

e) certified pressurized (type 'p');

f) certified increased safety (type 'e');

g) certified encapsulated (type 'm');

h) certified sand filled (type 'q');

i) certified specially (type 's');

j) 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 tank bulkhead;

k) through runs of cable.

(3) In Zone 2

a) equipment which is allowed to be installed in Zone 1;

b) non-sparking electrical equipment 'n';

c) the type which ensures the absence of sparks and arcs and of 'hot spots' during its normal operation.

9.3.1.2 Equipment within a hazardous area is to be assessed and certificated or registered by the authorities approved by CCS. Automatic isolation of non-conforming flammable gas detection equipment is not to be used in place of approved equipment.

9.3.2 Choice and installation of cables

9.3.2.1 The manufacturing and testing of cables are to comply with the relevant requirements of approved standards.

9.3.2.2 Cables and their fittings are to be appropriate to the hazardous area where they will be installed, taking account of the mechanical, chemical and corrosion factors etc.

9.3.2.3 Where cables pass through a deck or bulkhead within hazardous area, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

CHAPTER 10 MECHANICAL VENTILATION

Section 1 GENERAL PROVISIONS

10.1.1 Goal

10.1.1.1 The goal of this Chapter is to provide for the ventilation to ensure safe operation of gas fuelled machinery and equipment.

10.1.2 Functional requirements

10.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (2), 1.1.3.2 (5), 1.1.3.2 (8), 1.1.3.2 (10), 1.1.3.2 (12) to 1.1.3.2 (14) and 1.1.3.2 (17) of the Rules.

10.1.3 General requirements

10.1.3.1 Any ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces. The ventilation is to function at all temperatures and environmental conditions the ship is intended to operate in.

10.1.3.2 Electric motors for ventilation fans are not to be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

10.1.3.3 Design of ventilation fans serving spaces containing gas sources is to fulfil the following:

(1) Ventilation fans are not to produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction defined as:

① impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

② impellers and housings of non-ferrous metals;

③ impellers and housings of austenitic stainless steel;

④ impellers of aluminium alloy or magnesium alloy and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

⑤ any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

(2) In no case is the radial air gap between the impeller and the casing to be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

(3) Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and is not to be used in these places.

10.1.3.4 Ventilation systems required to avoid any gas accumulation are to consist of independent fans, each of sufficient capacity, unless otherwise specified in the Rules.

10.1.3.5 Air inlets for hazardous spaces are to be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous spaces are to be taken from non-hazardous areas at least 1.5 m far away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gastight and have over-pressure relative to this space.

10.1.3.6 Air outlets from non-hazardous spaces are to be located outside hazardous areas.

10.1.3.7 Air outlets from gas hazardous spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

10.1.3.8 The required capacity of the ventilation system is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

10.1.3.9 Non-hazardous spaces with entry openings to a hazardous area are to be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation is to be arranged according to the following:

(1) During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it is to be required to:

① proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and

② pressurize the space.

(2) Operation of the overpressure ventilation is to be monitored and in the event of failure of the overpressure ventilation:

① an audible and visual alarm is to be given at a manned location; and

② if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard① is to be required.

10.1.3.10 Non-hazardous spaces with entry openings to a hazardous enclosed space are to be arranged with an airlock and the hazardous space is to be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space is to be monitored and in the event of failure of the extraction ventilation:

(1) an audible and visual alarm is to be given at a manned location; and

(2) if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard② in the non-hazardous space is to be required.

10.1.3.11 The ventilation system is to ensure a good air circulation in the spaces served, and in particular ensure that any formation of air-pockets in the room is avoided.

10.1.3.12 Any ducting used for the ventilation of hazardous spaces is not to be through accommodation space, service space or other similar space.

10.1.3.13 Portable ventilation plants are to be provided in empty places or similar places within hazardous area which are not generally entered. Ventilation is to be provided before entrance into such places, and a notice board saying 'Ventilation needed' is to be provided outside of the spaces. The portable ventilation plant is to have an explosion-proof degree appropriate to the classification of gas hazardous area and hold a marine product certificate.

10.1.3.14 Ventilation fans serving the hazardous space are to be fitted with spares.

10.1.3.15 The shell of the fan is to be earthed.

10.1.3.16 Suitable protective screens of not more than 13 mm square mesh are to be fitted on vent outlets of hazardous spaces.

10.1.3.17 An audible and visual alarm is to be given at a manned location in the case of a failure of ventilation system.

10.1.3.18 Suitable isolation arrangements are to be provided to prevent a pipe where a fan or group of

---

① Refer to IEC 60092-502 Electrical Installations in Ships–Tankers–Special Features, Table 5.

② Refer to IEC 60092-502 Electrical Installations in Ships–Tankers–Special Features, Table 5.

fans is located, if it fails, forming a ventilation circuit to the pipes where other fans are located.

10.1.3.19 For mechanical ventilation systems of the extraction type within hazardous spaces, the outlet of each fan airline is to be arranged according to the area where combustible gas may be accumulated and normally located on the top of space.

10.1.3.20 For passenger ships required to meet the requirements for safe return to port, any opening within the safe area① is not to be located in an gas hazardous area, and any ventilation inlet within the safe area is to be at least 1.5 m away from the boundary of gas hazardous area.

Section 2 TANK CONNECTION SPACES

10.2.1 General requirements

10.2.1.1 The tank connection space is to be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour is to be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations is to be demonstrated by a risk assessment.

10.2.1.2 Approved automatic fail-safe fire dampers are to be fitted in the ventilation trunk for the tank connection space.

These dampers (at air inlet and outlet) are to comply with the appropriate requirements in IMO Resolution MSC.365(93), PART 3 of Resolution MSC.307(88) and IACS UI GC5.

10.2.1.3 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

10.2.1.4 Spaces containing bolted hatch to a tank connection space are to be fitted with independent mechanical forced ventilation system of extraction type, providing a ventilation capacity of at least 8 air changes per hour.

Section 3 MACHINERY SPACES

10.3.1 General requirements

10.3.1.1 The ventilation system for machinery spaces containing gas-fuelled consumers is to be independent of all other ventilation systems.

Spaces enclosed in the boundaries of machinery spaces (such as purifier's rooms, engine-room workshops and stores) are considered an integral part of machinery spaces containing gas-fuelled consumers and, therefore, their ventilation system does not need to be independent of the one of machinery spaces.

10.3.1.2 The required ventilation system is to be of continuous operation in the gas mode of gas consumer.

10.3.1.3 ESD protected machinery spaces are to have ventilation with a capacity of at least 30 air changes per hour. The ventilation system is to ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby

① Refer to SOLAS regulation II-2/21.

under normal operation the machinery spaces are ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

10.3.1.4 For ESD protected machinery spaces, the ventilation arrangements are to provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard① acceptable to CCS.

10.3.1.5 The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

Section 4 FUEL PREPARATION ROOMS

10.4.1 General requirements

10.4.1.1 Fuel preparation rooms are to be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

10.4.1.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

10.4.1.3 Ventilation systems for fuel preparation rooms are to be in operation when pumps or compressors are working.

10.4.1.4 Before the first starting of fuel supply system after the fuel preparation room has recovered a leak, or prior to the entry of fuel preparation room, restarting of pumps and compressors is not to be possible before 10 minutes of operation of ventilation system. Warning signs are to be posted at the corresponding control positions.

Section 5 BUNKERING STATIONS

10.5.1 General requirements

10.5.1.1 Bunkering stations that are not located on open deck are to be suitably ventilated to ensure that any vapour being released during bunkering operation will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation is to be provided in accordance with the risk assessment required by 5.2.1.1 of the Rules.

Section 6 DOUBLE PIPES

10.6.1 General requirements

10.6.1.1 Double pipes containing fuel piping are to be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not

① Refer to IEC 60079-10-1 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres.

applicable to double pipes in the engine-room if fulfilling 6.4.1.1(1) of the Rules.

10.6.1.2 The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms is to be independent of all other ventilation systems.

Double piping and gas valve unit spaces in gas safe engine-rooms are considered an integral part of the fuel supply systems and, therefore, their ventilation system does not need to be independent of other fuel supply ventilation systems provided such fuel supply systems contain only gaseous fuel.

10.6.1.3 The ventilation inlet for the double wall piping is always to be located in an open non-hazardous area away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water.

10.6.1.4 The capacity of the ventilation for a pipe duct or double wall piping may be below 30 air changes per hour if a flow velocity of minimum 3 m/s is ensured. The flow velocity is to be calculated for the duct with fuel pipes and other components installed.

10.6.1.5 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

Section 7 GAS VALVE UNIT SPACES

10.7.1 General requirements

10.7.1.1 The ventilation system for gas valve unit spaces is to comply with the requirements for ventilation systems of Section 6 of this Chapter.

CHAPTER 11 ELECTRICAL INSTALLATIONS

Section 1 GENERAL PROVISIONS

11.1.1 Goal

11.1.1.1 The goal of this Chapter is to provide for electrical installations that minimizes the risk of ignition in the presence of a flammable atmosphere.

11.1.2 Functional requirements

11.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1) to (2), (4), (7), (8), (11), (13) and (16) to (18) of the Rules. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

11.1.3 General requirements

11.1.3.1 Electrical installations are to be in compliance with a standard① at least equivalent to those acceptable to CCS.

11.1.3.2 Electrical equipment or wiring is not to be installed in hazardous areas unless it is essential for operational purposes or safety enhancement.

11.1.3.3 Where electrical equipment is located in the hazardous area as provided in 11.1.3.2 of this Section, it is to be selected, installed and maintained in accordance with standards② at least equivalent to those acceptable to CCS.

Equipment for hazardous areas are to be evaluated, certified or listed by an accredited authority recognized by CCS.

11.1.3.4 A failure modes and effects analysis (FMEA) of single failure for electrical generation and distribution systems used for maintaining the tank pressure and hull temperature within normal operating limits are to be conducted and documented according to the standards③ acceptable to CCS.

11.1.3.5 The lighting system (if any) in hazardous areas is to be divided between at least two branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a non-hazardous area.

11.1.3.6 The installation on board of the electrical equipment is to be such as to ensure its safe bonding to the hull.

11.1.3.7 Submerged bumps are to be provided with means to give an alarm and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown is to give an audible and

---

① Refer to IEC 60092 series standards, as applicable.

② Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 6009260092:-502.

③ Refer to IEC 60812.

visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

11.1.3.8 Submerged fuel pump motors and their supply cables may be fitted in fuel containment systems. Fuel pump motors are to be capable of being isolated from their electrical supply during gas-freeing operation.

11.1.3.9 For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type is to be de-energized upon loss of overpressure in the space.

11.1.3.10 Electrical equipment for propulsion, power generation, maneuvering, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, is to be of a certified safe type.

11.1.3.11 Emergency lighting or temporary emergency lighting is to be provided near the bunkering station.

11.1.3.12 The electronic control system, gas control system and gas safety system of gas engine are to be supplied from two power supply, of which one is a main source of electrical power and the other is a storage battery or an uninterruptible power system (UPS), other than off-line UPS. They are to be capable of automatically converting to the storage battery or UPS in the event of failure of the main source of electrical power, and giving an alarm both locally and on the bridge. The period of power supply of the storage batteries is to be a minimum of 30 min. When only storage batteries are used as the main power, two separate power supply is required for the systems mentioned above.

CHAPTER 12 CONTROL, MONITORING AND SAFETY SYSTEMS

Section 1 GENERAL PROVISIONS

12.1.1 Goal

12.1.1.1 The goal of this Chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other chapters of the Rules.

12.1.2 Functional requirements

12.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1), (2), (11), (13) to (15), (17) and (18) of the Rules. In particular the following apply:

(1) The control, monitoring and safety systems of the gas consumers are to be so arranged that the remaining power for propulsion and power generation is in accordance with 6.1.3.1 of the Rules in the event of single failure;

(2) A gas safety system is to be arranged to close down the gas supply system automatically, upon failure in systems as described in Table 12.4.3 of this Chapter and upon other fault conditions which may develop too fast for manual intervention;

(3) Ffor ESD protected machinery spaces, the safety system is to shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

(4) The safety functions are to be arranged in a dedicated gas safe system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

(5) The safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

(6) Where two or more gas supply systems are required to meet the regulations, each system is to be fitted with its own set of independent gas control and gas safety systems.

12.1.3 General requirements

12.1.3.1 Suitable instrumentation devices are to be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole gas fuel system including bunkering.

12.1.3.2 A bilge well in each tank connection space of an independent fuel tank is to be provided with both a level indicator and a temperature sensor. Alarm is to be given at high level in the bilge well. Low temperature indication is to activate the safety system. A level indicator is only used to indicate the alarm status and, therefore, it can be a type of level switch (floating switch).

12.1.3.3 For tanks not permanently installed in the ship, a monitoring system is to be provided as for permanently installed tanks.

12.1.3.4 The requirements for monitoring, control and safety are given in Table 12.4.2 and Table 12.4.3 of this Chapter. Table 12.4.2 contains the requirements for gas control systems, and Table 12.4.3 contains the requirements for gas safety systems. Where an alarm is required by both Table 12.4.2 and Table 12.4.3, it is to be activated by the separate sensors of gas control system and gas safety system.

12.1.3.5 An alarm related to gas detection may be given by the gas safety system and also by a separate gas detection system which will activate the gas safety system.

12.1.3.6 The safety system is to output electrical signals and its alarms and protection actions to be activated are not to be dependent on the gas control system.

Section 2 MONITORING AND CONTROL

12.2.1 Bunkering and fuel tanks

12.2.1.1 Level indicators for fuel tanks

(1) Each fuel tank is to be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the fuel tank is operational. The device(s) is(are) to be designed to operate throughout the design pressure range of the fuel tank and at temperatures within the fuel operating temperature range.

(2) Where only one liquid level gauge is fitted, it is to be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

(3) Fuel tank liquid level gauges may be of the following types:

.1 indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or

.2 closed devices, which do not penetrate the fuel tank, such as devices using radio-isotopes or ultrasonic devices; or

.3 closed devices, which penetrate the fuel tank （only for ships engaged on domestic voyages), being part of the closed system and capable of preventing gas fuel spillage, such as float-type systems, electronic probes, magnetic probes, differential pressure sensors and bubbler tube type indicator. The device is to be considered tank connection. Where the closed device is not directly installed on the tank, a shutoff valve is to be fitted near the tank as far as practicable.

(4) An indirect indication is to be provided on the navigation bridge, continuously manned central control room (station) or onboard safety centre.

12.2.1.2 Overflow control

(1) Each liquefied gas fuel tank is to be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

(2) An additional sensor is to be fitted to automatically actuate a shutoff valve at the high high liquid level in the tank in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the fuel tank from becoming fuel full. The sensor is to be independent from the liquid level sensor required in 12.2.1.2 (1) of this Section.

(3) The position of the sensors in the fuel tank is to be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high level alarms is to be conducted by raising the fuel liquid level in the fuel tank to the alarm point.

The expression 'each dry-docking' refers to:

（1） For cargo ships, the survey of the outside of the ship's bottom required for the renewal of the Cargo Ship Safety Construction Certificate and/or the Cargo Ship Safety Certificate; and

（2）For passenger ships, the survey of the outside of the ship's bottom to be carried out in dry docking according to CCS Rules for Classification of Sea-going Steel Ships or Regulations for Classification of Sea-going Ships Engaged on Domestic Voyages or Regulations for Classification of Inland Waterways Ships.

(4) All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, are to be capable of being functionally tested. Systems are to be tested prior to fuel operation in accordance with 14.2.5 of the Rules.

(5) Where arrangements are provided for overriding the overflow control system, they are to be such that inadvertent operation is prevented. When this override is operated, continuous visual indication is to be provided at the navigation bridge, continuously manned central control station or onboard safety centre.

12.2.1.3 The vapour space of each fuel tank is to be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control room or onboard safety centre.

12.2.1.4 The pressure indicators are to be clearly marked with the highest and lowest pressure permitted in the fuel tank.

12.2.1.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm are to be provided at the navigation bridge, continuously manned central control room or onboard safety centre. Alarms are to be activated before the set pressures of the safety valves are reached.

12.2.1.6 Each fuel pump or compressor discharge line and each liquid and vapour fuel manifold are to be provided with at least one local pressure indicator.

12.2.1.7 Local-reading manifold pressure indicator are to be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

12.2.1.8 Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere are to be provided with pressure indicator.

12.2.1.9 At least one of the pressure indicators provided is to be capable of indicating throughout the operating pressure range.

12.2.1.10 For submerged fuel-pump motors and their supply cables, arrangements are to be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shut-down may be accomplished by sensing low pump discharge pressure, low motor current or low-liquid level. This shutdown is to give an audible and visual alarm at the navigation bridge, continuously manned central control room or onboard safety centre.

12.2.1.11 Each fuel tank is to be provided with devices to measure and indicate the temperature of the fuel in at least three locations:

(1) at the bottom of the tank;

(2) at the middle of the tank;

(3) at the top of the tank below the highest allowable liquid level.

For independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, the devices for fuel temperature measurement and indication need to be installed only on the discharge lines at the bottom of the tank, as close as possible to the tank.

12.2.2 Bunkering control

12.2.2.1 Control of the bunkering is to be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by 12.2.1.11 of this Section, and tank level are to be monitored. Remotely controlled valves required by 5.3.1.3 and 8.3.3.8 of the Rules are to be capable of being operated from this location. Overfill alarm and automatic shutdown are also to be indicated at this location.

12.2.2.2 If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm is to be provided at the bunkering control location.

12.2.2.3 If gas is detected in the ducting around the bunkering lines, an audible and visual alarm and emergency shutdown are to be provided at the bunkering control location.

12.2.3 Gas compressors

12.2.3.1 Compressors are to be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms are to include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

12.2.3.2 Temperature monitoring for the bulkhead shaft glands and bearings is to be provided, which automatically gives a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

12.2.4 Heat exchangers

12.2.4.1 The heat-transfer medium temperature and circulating flow of heat exchanger are to be monitored. An low temperature alarm is to be activated at the actual heat-transfer medium temperature below the design permissible value. If the heat-transfer medium cycle stops, automatic shutdown of tank master valve and stop of fuel pump are to be activated to avoid icing of the heat-transfer medium.

12.2.4.2 The temperature of the heated medium at the heat exchanger outlet is to be monitored, and a low temperature alarm is to be activated. In the case of low temperature of heated medium at the heat exchanger outlet, automatic shutdown of shutoff valves on heat exchanger supply line is to be provided.

12.2.5 Gas engines

12.2.5.1 In addition to diesel engine monitoring provided in accordance with part C of SOLAS chapter II-1 and CCS Rules for Classification of Sea-going Steel Ships (in case of ships engaged on international voyages) or Rules for the Construction of Sea-going Ships Engaged on Domestic Voyages or Rules for the Construction of Inland Waterways Steel Ships (in case of ships engaged on domestic voyages), as applicable, indicators are to be fitted at the navigation bridge, engine control room and control console at engine for:

(1) operation of the engine in case of gas-only engines; or

(2) operation and mode of operation of the engine in case of dual fuel engines.

12.2.6 Ventilation monitoring

12.2.6.1 Any loss of the required ventilating capacity is to give an audible and visual alarm at the navigation bridge or continuously manned central control station or onboard safety centre.

12.2.6.2 Acceptable means to confirm that the ventilation system has the 'ventilating capacity' required in 12.2.6.1 of this Section in its operation are to be, but not be limited to:

（1） monitoring of the ventilation electric motor or fan operation combined with underpressure indication; or

（2） monitoring of the ventilation electric motor or fan operation combined with ventilation flow indication; or

（3） monitoring of ventilation flow rate to indicate that the required air flow rate is established.

12.2.6.3 For ESD protected machinery spaces, the safety system is to be activated upon loss of ventilation in engine-room.

12.2.6.4 For tank connection spaces, fuel preparation rooms and double walled pipes (ventilation ducts), the failure of internal ventilation is to activate the safety system.

Section 3 GAS DETECTION AND FIRE DETECTION

12.3.1 Gas detection

12.3.1.1 Permanently installed gas detectors are to be fitted in:

(1) tank connection spaces;

(2) all ducts around double pipes;

(3) machinery spaces containing gas piping, gas equipment or gas consumers, except for gas-safety machinery spaces;

(4) compressor rooms and fuel preparation rooms;

(5) other enclosed spaces containing fuel piping or other fuel equipment without ducting;

(6) other enclosed/semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;

(7) airlocks;

(8) gas heating circuit expansion tanks;

(9) motor rooms associated with the fuel systems;

(10) enclosed/semi-enclosed bunkering stations;

(11) gas valve unit spaces, which may be considered as part of the ventilated duct provided that they connect to ventilated duct and have an inner space of not more than 2 m3;

(12) at ventilation inlets to accommodation and machinery spaces which may contain flammable gas, if required based on the risk assessment required in 1.1.6 of the Rules.

12.3.1.2 The two permanently installed gas detectors as required by 12.3.1.1 of this Section are to be independent and close to each other for redundancy reasons. If provided with self-examination function, only one detector is allowed with spares provided for timely replacing.

12.3.1.3 Where a gas detector with self-examination function is used, the detection of its own fault is to be treated as the detection of high gas concentration by the gas safety system or detection system.

12.3.1.4 In each ESD protected machinery space, redundant gas detection systems are to be provided.

12.3.1.5 The number of detectors in each space is to be considered taking into account the size, arrangement and ventilation of the space.

12.3.1.6 The detection equipment is to be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test may be used to find the best arrangement.

12.3.1.7 Gas detection equipment is to be designed, installed and tested in accordance with a recognized standard①.

12.3.1.8 An audible and visible alarm is to be activated at a fuel vapour concentration of 20% of LEL. The safety system is to be activated at 40% of LEL at two detectors (see footnote 1 in Table 12.4.3 of this Section).

---

① Refer to IEC 60079-29-1 – Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable detectors.

12.3.1.9 For ventilated ducts around gas pipes in the machinery spaces containing gas engines, the alarm limit can be set to 30% of LEL. The safety system is to be activated at 60% of LEL at two detectors (see footnote 1 in Table 12.4.3 of this Section).

12.3.1.10 Audible and visible alarms from the flammable gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station.

12.3.1.11 Flammable gas detection required by this Section is to be continuous without delay.

12.3.1.12 Gas detection equipment installed in interbarrier spaces and fuel storage hold spaces of independent tanks other than type C are to be capable of detecting gas concentration from 0 to 100% in volume.

12.3.1.13 One portable flammable gas detector is to be provided for the crew to detect the flammable gas in rooms.

12.3.1.14 Safety actions at fire detection in the machinery space containing gas engines and fuel storage hold space of independent tank are to be provided according to Table 12.4.3 of this Section.

Section 4 CONTROL AND SAFETY FUNCTIONS OF FUEL SUPPLY SYSTEMS

12.4.1 General requirements

12.4.1.1 If the fuel supply is shut off due to activation of an automatic stop valve, the fuel supply is not to be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A conspicuous notice giving instruction to this effect is to be placed at the operating station for the shutoff valves in the fuel supply lines.

12.4.1.2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply is not to be operated until the leak has been found and dealt with. Instructions to this effect are to be placed in a conspicuous position in the machinery space.

12.4.1.3 A caution placard or signboard is to be permanently fitted in the machinery space containing gas engines stating that heavy lifting, implying danger of damage to the fuel pipes, is not to be done when the engine(s) is running on gas.

12.4.1.4 Compressors, pumps and fuel supply are to be arranged for manual remote emergency stop from the following locations as applicable:

(1) navigation bridge;

(2) cargo control room;

(3) onboard safety centre;

(4) engine control room;

(5) fire control station; and

(6) adjacent to the exit of fuel preparation rooms.

The gas compressor is also to be arranged for manual local emergency stop.

12.4.1.5 Where the safety measures required in Table 12.4.2 and Table 12.4.3 of this Chapter involve fuel bunkering, the indication, alarm and safety actions are to be arranged in the bunkering control location and other safe locations. The alarms specified in Table 12.4.3 of this Chapter are to be arranged in the navigation bridge or continuously manned control room.

12.4.1.6 In addition to the actions listed in Table 12.4.3 of this Chapter, the followings are to provided for gas-only systems in case of failure of ventilation of machinery space:

(1) For electrical propulsion systems serving for multiple engine rooms, another engine is to start. The first engine is to automatically shutdown at the connection of the second engine to the busbar;

(2) For direct propulsion systems serving for multiple engine rooms, the engines contained in the machinery space with loss of ventilation are to manually shutdown provided that there are at least 40% of the effective propulsion power remained and normal power supply serving for navigation;

(3) For single engine rooms, the master gas fuel valve and block-and-bleed valves on the gas supply pipe which is ready for the loss of ventilation of gas double pipe or loss of inert gas pressure, are to automatically shutdown.

12.4.1.7 For passenger ships required to meet the requirements for safe return to port, the monitoring function of gas supply system is to be arranged and achieved at the onboard safety centre①.

12.4.1.8 In cases where the ship's main power is from a gas-only generator set(s), overriding may be permissible for the required start of the first main generator to allow opening the master gas valve to supply gas fuel and starting the main generator in the event of no power supply to heat exchanger and related fans, provided that:

（1） Start the gas detection system and gas safety system before starting the main generator;

（2） In an overriding state, the display equipment of the control system and safety system related to gas supply is to indicate the current system being out-of-control in a clear position, and the fan motor and heat exchanger are not opened;

（3） The relevant fan motors and heat exchangers are to be able to start by manually/automatically after starting the main generator, and the overriding is to be removed immediately after normal operation of the system;

（4） Means are to be provided for preventing the overriding being started by mistake.

12.4.2 Monitoring of gas control systems

Monitoring of Gas Control Systems Table 12.4.2

Parameters	Alarm	Automatic shutdown of tank master valve[1]	Automatic shutdown of master gas fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
Compressors and heat exchangers					
Low compressor inlet pressure	×				
Low compressor output pressure	×				
High compressor discharge pressure	×				

① Refer to SOLAS Regulation II-2/23.

Failure of compressor operation	×				
Low temperature of the heat-transfer medium of the heat exchanger	×				
Stop of the heat medium of the heat exchanger	×	×			Stop of fuel pump at the same time
Low outlet temperature of the heat exchanger	×				
Low-low outlet temperature of the heat exchanger	×	×	×		
1）The valves referred to in 6.2.1.1.					

12.4.3 Monitoring of gas safety systems

Monitoring of Gas Safety Systems **Table 12.4.3**

Parameters	Alarm	Automatic shutdown of tank master valve[6]	Shutdown of master fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
Fuel tanks, bunkering stations and bunkering lines					
High liquid level in tank	×				
High pressure in tank	×				
Low pressure in tank	×				See 12.2.1.5 of this Chapter
High-high level in tank	×			×	Only alarm not in the bunkering conditions
Low cable level of submerged bump	×				Stop of fuel pump
Gas detection of in enclosed or semi-enclosed bunkering station at 20% LEL	×				
Gas detection on two detectors[1] in enclosed or semi-enclosed bunkering station at 40% LEL	×			×	
Loss of ventilation in double pipe (duct)	×				
Gas detection in double pipe (duct) at 20% LEL	×				
Gas detection on two detectors[1] in double pipe (duct) at 40% LEL	×			×	
Fuel storage hold spaces, tank connection spaces and interbarrier spaces					
Gas detection in tank connection	×				

Parameters	Alarm	Automatic shutdown of tank master valve[6]	Shutdown of master fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
space at 20% LEL					
Gas detection on two detectors[1] in tank connection space at 40% LEL	×	×			
Fire detection in fuel storage hold space	×				
Fire detection in ventilation trunk for fuel containment system below deck	×				
Bilge well high level in tank connection space	×				
Bilge well low temperature in tank connection space	×	×			
Reduced ventilation of tank connection space	×				
Loss of ventilation in tank connection space	×	×			Stop of fuel pump simultaneously
Gas detection in interbarrier space at 20% LEL	×				See 12.3.1.1 (6) of this Chapter
Gas detection in fuel storage hold space at 20% LEL	×				See 12.3.1.1 (6) of this Chapter
Fuel preparation rooms					
Gas detection in fuel preparation room at 20% LEL	×				
Gas detection on two detectors[1] in fuel preparation room at 40% LEL	×	×[2]			
High level in bilge well of fuel preparation room	×				
Low temperature in bilge well of fuel preparation room	×	×			
Reduced ventilation in fuel preparation room	×				
Loss of ventilation in fuel preparation room	×	×			
High temperature of bulkhead shaft gland and bearing	×				See 12.2.3.2 of this Chapter

Parameters	Alarm	Automatic shutdown of tank master valve[6]	Shutdown of master fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
Gas supply lines located between the tank and the machinery space					
Gas detection in duct between tank and machinery space at 20% LEL	×				
Gas detection on two detectors[1] in duct between tank and machinery space at 40% LEL	×	×[2]			
Reduced ventilation in duct between tank and machinery space containing gas-fuelled engines	×				
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines[5]	×		×[2]		
Gas valve unit spaces					
Gas detection on one detector in gas valve unit space at 20% LEL	×				
Gas detection on two detectors[1] in gas valve unit space at 40% LEL	×		×[3]		
Loss of ventilation in gas valve unit space	×		×[3]		
Machinery space containing gas-fuelled engines					
Fire detection in machinery space containing gas-fuelled engines	×				
Rapture detection of gas supply piping in machinery space	×		×[8]		Only applicable to the scenarios referred to in 6.2.1.10 of the Rules
Gas detection in double pipe (duct) in machinery space containing gas-fuelled engines at 30% LEL	×				If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors[1] in double pipe (duct) in machinery space containing gas-	×		×[3]		If double pipe fitted in machinery space

Parameters	Alarm	Automatic shutdown of tank master valve[6]	Shutdown of master fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
fuelled engines at 60% LEL					
Gas detection above engine in gas safety machinery space at 20% LEL	×				See 6.4.1.2 (2) of the Rules
Gas detection on two detectors[1] above engine in gas safety machinery space at 40% LEL	×		×[7]		See 6.4.1.2 (2) of the Rules
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	×				
Gas detection on two detectors[1] in ESD protected machinery space containing gas-fuelled engines at 40% LEL	×		×		It is also to disconnect non certified safe electrical equipment in machinery space
Reduced ventilation in double pipe (duct) in machinery space containing gas-fuelled engines[5]	×				
Loss of ventilation in double pipe (duct) in machinery space containing gas-fuelled engines[5]	×		×[3]		If double pipe fitted in machinery space containing gas-fuelled engines
Reduced ventilation in ESD protected machinery space containing gas-fuelled engines	×				
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	×		×		
Miscellaneous					
Abnormal pressure in gas supply line	×				
Failure of working medium for valve control	×		×[4]		Time delayed as found necessary
Automatic shutdown of engine (engine failure)	×		×[4]		
Manually activated emergency shutdown of engine	×		×		
Manually shutdown fuel supply	×		×		See 12.2.1.4 of this Chapter

Parameters	Alarm	Automatic shutdown of tank master valve[6]	Shutdown of master fuel valve and double block and bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifolds	Comments
Manually shutdown fuel bunkering	×			×	See 12.2.2.1 of this Chapter
Gas detection in enclosed/semi-enclosed space where gas may accumulate at 20% LEL	×				See 12.3.1.1 (6) of this Chapter
Gas detection in air lock at 20% LEL	×				See 12.3.1.1 (7) of this Chapter
Gas detection in gas heating circuit expansion tank at 20% LEL	×				See 12.3.1.1 (8) of this Chapter
Gas detection in motor room associated with fuel system at 20% LEL	×				See 12.3.1.1 (9) of this Chapter

1) Two independent gas detectors located close to each other are required for redundancy reasons. For fixed flammable gas detector used with the self-examination function, the minimum quantity required for a separate space may be reduced to one.

2）If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

4）Only double block and bleed valves to close.

5）If the duct is protected by inert gas (see 6.4.1.1 (1) of the Rules) then loss of inert gas overpressure is to lead to the same actions as given in this table.

6）The valves referred to in 6.2.1.1 of the Rules.

7）Only applicable to dual fuel engines.

8）Alternatively, shutoff of a stop valve specially used in case of rapture of gas supply line.

CHAPTER 13 MANUFACTURE, WORKMANSHIP AND TESTING

Section 1 GENERAL PROVISIONS

13.1.1 General requirements

13.1.1.1 In addition to this Chapter, manufacture, workmanship, testing, inspections and documentation are to be in accordance with CCS Rules, such as CCS Rules for Materials and Welding and Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, or recognized standards, as applicable.

13.1.1.2 Where post-weld heat treatment is specified or required, the properties of the base material are to be determined in the heat treated condition, in accordance with the applicable tables of Chapter 3 of the Rules, and the weld properties are to be determined in the heat treated condition in accordance with Section 3 of this Chapter. In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of CCS.

Section 2 GENERAL TESTING REQUIREMENTS AND SPECIFICATIONS

13.2.1 Tensile test

13.2.1.1 Tensile testing is to be carried out in accordance with CCS Rules for Materials and Welding.

13.2.1.2 Tensile strength, yield stress and elongation are to be to the satisfaction of CCS. For carbon-manganese steel and other materials with definitive yield points, consideration is to be given to the limitation of the yield to tensile ratio.

13.2.2 Toughness test

13.2.2.1 Acceptance tests for metallic materials are to include Charpy V-notch toughness tests unless otherwise specified by CCS. The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm×10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens are to be in accordance with CCS Rules for Materials and Welding, as applicable. The testing and requirements for specimens less than 5.0 mm in size are to be in accordance with recognized standards. Minimum average values for sub-sized specimens are shown in Table 13.2.2.1.

Minimum Average Energy for Sub-sized Charpy V-notch Table 13.2.2.1

Charpy V-notch specimen size (mm)	Minimum average energy of Three Charpy V-notch specimens (J)
10×10	KV

10×7.5	5/6 KV
10×5	2/3 KV

where: KV—— the energy values (J) specified in Table 3.3.1.1 (1) to Table 3.3.1.1 (4) of the Rules.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

13.2.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness are to be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in Figure 13.2.2.2.

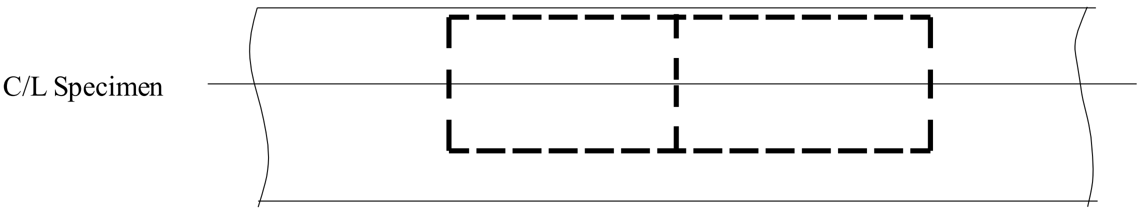
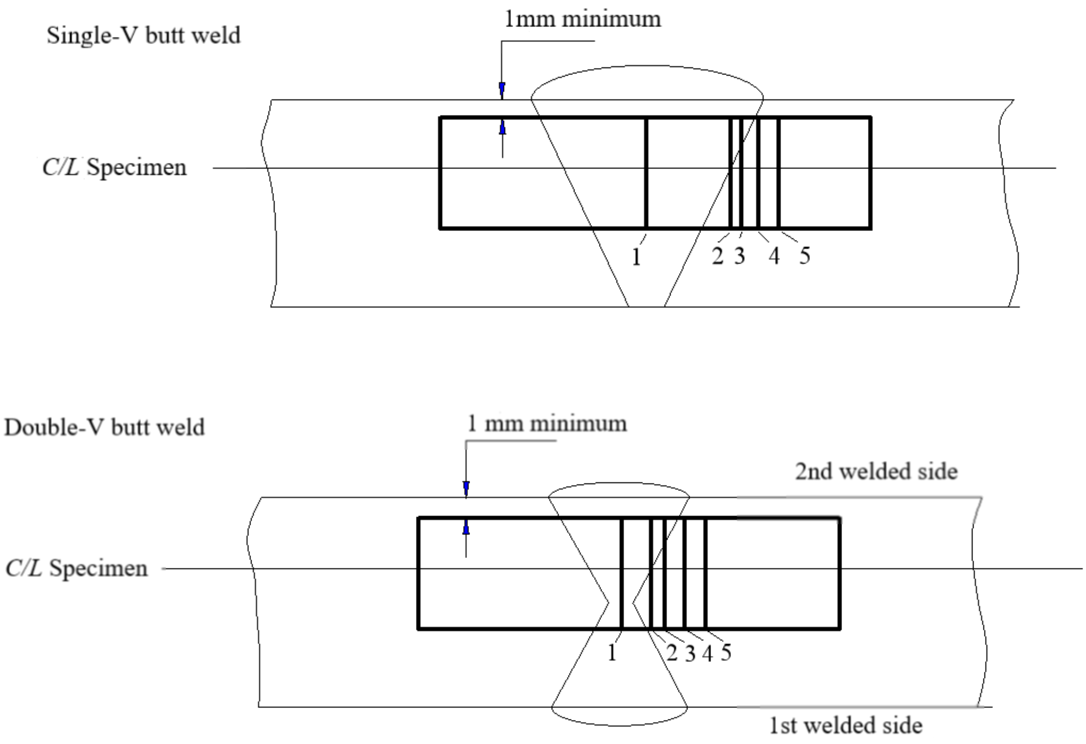


Figure 13.2.2.2 Orientation of base metal test specimen

13.2.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness are to be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases the distance from the surface of the material to the edge of the specimen is to be approximately 1 mm or greater. In addition, for double-V butt welds, specimens are to be machined closer to the surface of the second welded section. The specimens are to be taken generally at each of the following locations, as shown in Figure 13.2.2.3, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.



Notch locations in Figure 13.2.2.3:

.1 centreline of the weld;

.2 on fusion line;

.3 in heat-affected zone (HAZ), 1 mm from fusion line;

.4 in HAZ, 3 mm from fusion line;

.5 in HAZ, 5 mm from fusion line;

Figure 13.2.2.3 Orientation of weld test specimen

13.2.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.

13.2.3 Bend test

13.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. The bend tests, if required, are to be carried out according to CCS Rules for Materials and Welding.

13.2.3.2 The bend tests are to be transverse bend tests, which may be face, root or side bends at the discretion of CCS. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

13.2.4 Section observation and other testing

13.2.4.1 Macrosection, microsection observations and hardness tests may also be required by CCS, and they are to be carried out in accordance with recognized standards, where required.

Section 3 WELDING OF METALLIC MATERIALS AND NON-DESTRUCTIVE TESTING FOR FUEL CONTAINMENT SYSTEMS

13.3.1 General requirements

13.3.1.1 This Section is to apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steel, but these tests may be adapted for other materials. At the discretion of CCS, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

13.3.2 Welding consumables

13.3.2.1 Consumables intended for welding of fuel tanks are to be in accordance with CCS Rules for Materials and Welding, as applicable. Deposited weld metal tests and butt weld tests are to be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests are to be in accordance with recognized standards. The chemical composition of the deposited weld metal is to be recorded for information.

13.3.3 Welding procedure tests for fuel tanks and process pressure vessels

13.3.3.1 Welding procedure tests for fuel tanks and process pressure vessels are required for all butt welds.

13.3.3.2 The test assemblies are to be representative of:

(1) each base material;

(2) each type of consumable and welding process; and

(3) each welding position.

13.3.3.3 For butt welds in plates, the test assemblies are to be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test is to be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.

13.3.3.4 The following welding procedure tests for fuel tanks and process pressure vessels are to be carried out in accordance with Section 2 of this Chapter with specimens made from each test assembly:

(1) cross-weld tensile tests;

(2) longitudinal all-weld testing where required by the recognized standards;

(3) transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels;

(4) one set of three Charpy V-notch impacts, generally at each of the following locations, as shown in Figure 13.2.2.3;

(5) macrosection, microsection and hardness inspections may also be required.

13.3.3.5 Each test is to satisfy the following:

(1) tensile tests: cross-weld tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. For aluminium alloy, reference is to be made to 4.2.10.1 (4) of the Rules with regard to the requirements for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture is to be recorded for information;

For longitudinal tensile tests, the yield stress of the deposited weld metal is not to be less than the specified minimum yield stress of the parent metal or minimum yield stress considered in design.

(2) bend tests: no fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces; and

For bend tests of 5083 aluminium alloy, the material is to be bended in a diameter 5 times the thickness of the test pieces where its thickness is not more than 12.5 mm; and bended in a diameter 6 times the thickness of the test pieces where its thickness is more than 12.5 mm.

The test specimens are not to reveal any crack or other open defects exceeding 3 mm in length on the tension surface.

(3) Charpy V-notch impact tests: Charpy V-notch tests are to be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV) are to be no less than 27 J. The weld metal requirements for sub-size specimens and single energy values are to be in accordance with 13.2.2 of this Chapter. The results of fusion line and heat affected zone impact tests are to show a minimum average energy (KV) in accordance with the transverse or longitudinal regulations of the base material, whichever is applicable, and for sub-size specimens, the minimum average energy (KV) is to be in accordance with 13.2.2 of this Chapter. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards are to be in accordance with recognized standards.

13.3.3.6 Procedures tests for fillet welding are to be in accordance with CCS Rules for Materials and Welding. In such cases, consumables are to be so selected that exhibit satisfactory impact properties.

13.3.4 Welding procedure tests for piping

13.3.4.1 Welding procedure tests for piping are to be carried out and are to be similar to those detailed for fuel tanks in 13.3.3 of this Chapter.

13.3.5 Production weld tests

13.3.5.1 For all fuel tanks and process pressure vessels except membrane tanks, production weld tests are generally to be performed for approximately each 50 m of butt-weld joints and are to be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks are to be performed, except that the number of tests may be reduced subject to agreement with CCS. Tests other than those specified in 13.3.5.2 to 13.3.5.5 of this Chapter may be required for fuel tanks or secondary barriers.

13.3.5.2 The production tests for types A and B independent tanks are to include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The Charpy V-notch tests are to be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches are to be in the centre of the weld.

13.3.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 13.3.5.2 of this Chapter. Tensile tests are to meet 13.3.3.5 of this Chapter.

Longitudinal weld tensile tests are to be carried out for tanks and process pressure vessels, with the yield stress of the deposited weld metal not to be less than the specified minimum yield stress of the parent metal or minimum yield stress considered in design.

13.3.5.4 The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the production welds as defined in the material manufacturers' quality manual (QM).

13.3.5.5 The test requirements for membrane tanks are to be the same as the applicable test regulations listed in 13.3.3 of this Chapter.

13.3.6 Non-destructive testing

13.3.6.1 All test procedures and acceptance standards are to be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing is to be used in principle to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but in addition supplementary radiographic testing at selected locations is to be carried out to verify the results. Radiographic and ultrasonic testing records are to be retained.

Non-destructive testing is to comply with Chapter 7 of CCS Guidelines for Inspection of Hull Welds, as applicable. In the case of full penetration welds of fuel tanks (excluding membrane tanks), if using Chinese shipping standards (CB) or Japanese Industrial Standards (JIS), the acceptance is to be Grade I. If using ISO standards, the acceptance level for hull structure is to be according to the requirements for important areas.

13.3.6.2 For type A independent tanks where the design temperature is below -20°C, and for type B independent tanks regardless of temperature, all full penetration butt welds of the shell plating of fuel tanks are to be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in 13.3.6.1 of this Chapter.

13.3.6.3 In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, is to be examined by magnetic particle or dye penetrant methods as considered necessary.

13.3.6.4 For type C independent tanks, the extent of non-destructive testing is to be total or partial according to recognized standards, but the controls to be carried out are not to be less than that required in 13.3.6.5 and 13.3.6.6 of this Chapter.

13.3.6.5 Total non-destructive testing referred to in 4.2.15.2 (1) ③ of the Rules are as follows:

Radiographic testing:

(1) all butt welds over their full length;

Non-destructive testing for surface crack detection:

(1) all welds over 10% of their length;

(2) reinforcement rings around holes, nozzles, etc. over their full length.

As an alternative, ultrasonic testing, as described in 13.3.6.1 of this Chapter, may be accepted as a partial substitute for the radiographic testing. In addition, CCS may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

13.3.6.6 Partial non-destructive testing referred to in 4.2.15.2 (1) ③ of the Rules are as follows:

Radiographic testing: all butt welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed;

Non-destructive testing for surface crack detection: reinforcement rings around holes, nozzles, etc. over their full length;

Ultrasonic testing: as may be required by CCS in each instance.

13.3.6.7 The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM).

13.3.6.8 Inspections of piping are to be carried out in accordance with Chapter 3 of the Rules and CCS Rules for Materials and Welding, as applicable.

13.3.6.9 The secondary barrier is to be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell are to be tested by radiographic testing.

Section 4 OTHER REQUIREMENTS FOR CONSTRUCTION IN METALLIC MATERIALS

13.4.1 General requirements

13.4.1.1 Inspections and non-destructive testing of welds are to be in accordance with the requirements in 13.3.5 and 13.3.6 of this Chapter. Where higher standards or tolerances are assumed in the design, they are also to be satisfied.

13.4.2 Independent tanks

13.4.2.1 For type C tanks and type B tanks primarily constructed of bodies of revolution, the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, are to comply with recognized standards. The tolerances are related to the buckling analysis referred to in 4.2.14.3 of the Rules.

13.4.3 Secondary barriers

13.4.3.1 During construction the requirements for testing and inspection of secondary barriers are to be approved or accepted by CCS (see 4.2.3.2 (5) and 4.2.3.2 (6) of the Rules).

13.4.4 Membrane tanks

13.4.4.1 The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures are to be developed during the prototype testing programme.

Section 5 TESTING

13.5.1 Testing and inspections during construction

13.5.1.1 All liquefied gas fuel tanks and process pressure vessels are to be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 13.5.2 to 13.5.5 of this Chapter, as applicable for the tank type.

13.5.1.2 All tanks are to be subject to a tightness test which may be performed in combination with the pressure test referred to in 13.5.1.1 of this Chapter.

13.5.1.3 The gas tightness of the fuel containment system with reference to 4.1.3.3 of the Rules is to be tested.

13.5.1.4 The requirements for inspection of secondary barriers are to be decided by CCS in each case, taking into account the accessibility of the barrier (see 4.2.3.2 of the Rules).

13.5.1.5 CCS may require that for ships fitted with novel type B independent tanks, or tanks designed according to 4.2.17 of the Rules, at least one prototype tank and its support are to be instrumented with strain gauges or other suitable equipment to confirm stress levels during the testing required in 13.5.1.1 of this Chapter. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

13.5.1.6 The overall performance of the fuel containment system is to be verified for compliance with the design parameters during the first LNG bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements of CCS. Records of the performance of the components and equipment, essential to verify the design parameters, are to be maintained on board and be available to CCS.

13.5.1.7 The fuel containment system is to be inspected for cold spots during or immediately following the first LNG bunkering. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out in accordance with recognized standards.

13.5.1.8 Heating arrangements, if fitted in accordance with 4.2.11.1 (3) and 4.2.11.1 (4) of the Rules, are to be tested for required heat output and heat distribution.

13.5.2 Type A independent tanks

13.5.2.1 All type A independent tanks are to be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test is to be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions are to simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.

13.5.3 Type B independent tanks

13.5.3.1 Type B independent tanks are to be subjected to a hydrostatic or hydro-pneumatic pressure testing according to the requirements for type A independent tanks specified in 13.5.2 of this Chapter.

13.5.3.2 The maximum primary membrane stress or maximum bending stress in primary members under test conditions is not to exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength, the prototype testing is to be monitored by the use of strain gauges or other suitable equipment.

13.5.4 Type C independent tanks and other pressure vessels

13.5.4.1 Each pressure vessel is to be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than $1.5P_0$ (P_0 is the design vapour pressure). In no case during the pressure test the calculated primary membrane stress at any point is to exceed 90% of the yield strength of the material at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype testing is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

13.5.4.2 The temperature of the water used for the test is to be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

13.5.4.3 The pressure is to be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

13.5.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 13.5.4.1 to 13.5.4.2 of this Chapter.

13.5.4.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, requirements in 13.5.4.1 of this Chapter are to be fully complied with.

13.5.4.6 After completion and assembly, each pressure vessel and its related fittings are to be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in

13.5.4.1 or 13.5.4.4 of this Chapter as applicable.

13.5.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks is to be considered on an individual case basis. Such testing is only to be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

13.5.5 Membrane tanks

13.5.5.1 The design development testing required in 4.2.16.1 ② of the Rules is to include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads at all filling levels. This will culminate in the construction of a prototype scaled model of the complete liquefied gas fuel containment system. Testing conditions considered in the analytical and physical model are to represent the most extreme service conditions the liquefied gas fuel containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in 4.2.3.2 of the Rules may be based on the results of testing carried out on the prototype scaled model.

13.5.5.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes is to be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure are to be determined by analyses or tests.

13.5.5.3 In ships fitted with membrane liquefied gas fuel containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, are to be hydrostatically tested.

13.5.5.4 All hold structures supporting the membrane are to be tested for tightness before installation of the liquefied gas fuel containment system.

13.5.5.5 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

Section 6 WELDING, POST-WELD HEAT TREATMENT AND NON-DESTRUCTIVE TESTING

13.6.1 Welding

13.6.1.1 Welding is to be carried out in accordance with 13.3 of this Chapter.

13.6.2 Post-weld heat treatment

13.6.2.1 Post-weld heat treatment is to be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steel and to comply with the relevant requirements of CCS Rules for Materials and Welding. CCS may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

13.6.3 Non-destructive testing

13.6.3.1 In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out according to this Section, the tests required in 13.6.3.2 to 13.6.3.5 of this Chapter are to be required.

13.6.3.2 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with:

(1) design temperatures colder than minus 10°C; or

(2) design pressure greater than 1.0 MPa; or

(3) gas supply pipes in ESD protected machinery spaces; or

(4) inside diameters of more than 75 mm; or

(5) wall thicknesses greater than 10 mm.

13.6.3.3 When such butt welded joints of piping sections are made by automatic welding procedures in the manufacturing shop, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed by CCS, but in no case to less than 10% of each joint. If defects are revealed, the extent of examination is to be increased to 100% and is to include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently.

13.6.3.4 The radiographic or ultrasonic inspection requirements may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.

13.6.3.5 For other butt-welded joints of pipes not covered by 13.6.3.2 and 13.6.3.4 of this Chapter, spot radiographic or ultrasonic inspection or other non-destructive tests are to be carried out depending upon service, position and materials at the decisions of CCS. In general, at least 10% of butt-welded joints of pipes are to be subjected to radiographic or ultrasonic inspection.

Section 7 TESTING REQUIREMENTS

13.7.1 Type testing of piping components

13.7.1.1 Each type of valve intended to be used at a working temperature below minus 55℃ is to be subject to the type tests specified in 13.7.1.2 to 13.7.1.5 of this Chapter.

13.7.1.2 Each size and type of valve are to be subjected to seat tightness testing over the full range of operating pressures and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates are to satisfy the requirements of CCS. During the testing, satisfactory operation of the valve is to be verified.

13.7.1.3 The flow or capacity is to be certified to a recognized standard for each size and type of valve.

13.7.1.4 Pressurized components are to be pressure tested to at least 1.5 times the design pressure.

13.7.1.5 For emergency shutdown valves, with materials having melting temperatures lower than 925℃, the type testing is to include a fire test to a standard① accepted by CCS. However, if the valve components are made of materials having a melting point below 925℃ which will not contribute to the shell or seat tightness of the valve, the valve does not need be subject to a fire test.

13.7.1.6 Product testing of valves

(1) The Surveyor is to be present during testing of all valves in the manufacturer. The body of each valve is to be subjected to a hydraulic test at 1.5 times the design pressure; the seat and rod of valve other

---

① E.g., GB/T 22218 / ISO 19921: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods, and GB/T 22219 / ISO 19922: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

than safety valve are to be subjected to a leakage test at 1.1 times the design pressure. In addition, each size and type of valve (other than safety valve) intended to be used at a working temperature below minus 55℃ is to be subject to a low temperature test to 10% of the products at least, including valve operation and leakage verification. The test at the set pressure of safety valve is to be carried out at the ambient temperature;

（2）If the manufacturer requests an alternative to the above tests, the certification survey of valve may be carried out as follows:

① Valves intended to be used at a working temperature below minus 55℃ are subjected to a prototype test according to 13.7.1.6 of this Chapter;

② The manufacturer has an approved quality system which has been assessed and certificated by CCS, and is periodically audited;

③ The quality control plan includes: the body of each valve is to be subjected to a hydraulic test at 1.5 times the design pressure; the seat and rod of valve other than safety valve are to be subjected to a leakage test at 1.1 times the design pressure. The test at the set pressure of safety valve is to be carried out at the ambient temperature. The manufacturer is to keep test records; and

④ Each size and type of valve (other than safety valve) intended to be used at a working temperature below minus 55℃ is to be subject to a low temperature test to 10% of the products, including valve operation and leakage verification, witnessed by CCS Surveyor.

13.7.2 Expansion bellows

13.7.2.1 The type tests required in 13.7.2.2 to 13.7.2.5 of this Chapter are to be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable in 3.2.6.4 (3) of the Rules and where required by CCS, on those installed within the fuel tanks.

13.7.2.2 Elements of the bellows, not pre-compressed, but axially restrained are to be pressure tested at not less than 5 times the design pressure without bursting. The duration of the test is not to be less than 5 minutes.

13.7.2.3 A pressure test is to be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.

13.7.2.4 A cyclic test (thermal movements) is to be performed on a complete expansion joint, which is to withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.

13.7.2.5 A cyclic fatigue test (considering ship deformation) is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2×10^6 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

13.7.3 System testing

13.7.3.1 This Section applies to fuel piping inside and outside the fuel tanks. However, relaxation from these requirements for piping inside fuel tanks and open ended piping may be accepted by CCS.

13.7.3.2 After assembly, all fuel piping is to be subjected to a pressure test with a suitable fluid. The test pressure is to be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board are to be tested to at least 1.5 times the design pressure.

13.7.3.3 In double wall fuel piping systems, the outer pipe or duct is also to be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture.

The outer pipe or duct is to be pressure tested according to 2.7.1, Chapter 2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships to ensure gastight integrity and to show that it can withstand the expected maximum pressure at pipe rupture. If containing high pressure piping, the outer pipe or duct is to be pressure tested to at least 1 MPa.

13.7.3.4 After assembly on board, the fuel piping system is to be subjected to a leakage test using air, or other suitable medium to a pressure depending on the leakage detection method applied.

Fuel piping may be subjected to a leakage test according to 2.7.3, Chapter 2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

13.7.3.5 The tank connection space is to be subjected to a leakage test with air or other suitable medium and normally at a pressure not less than 0.015 MPa, unless otherwise required for the leakage testing methods adopted. After assembly on board, the outer pipe or ventilated duct of double walled pipe are to be subjected to a leakage test using air, or other suitable medium to a pressure not less than 1.25 times the design pressure in general, unless otherwise required for the leakage testing methods adopted.

13.7.3.6 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, are to be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of CCS.

13.7.3.7 Emergency shutdown valves in liquefied gas piping systems are to close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics are to be available on board, and the closing time is to be verifiable and repeatable.

13.7.3.8 The closing time of the valve referred to in 5.3.1.8 and 12.2.1.2 (2) of the Rules (i.e. time from shutdown signal initiation to complete valve closure) is not to be greater than:

$$\frac{3600U}{BR}\text{（second）}$$

where: U—— ullage volume at operating signal level (m^3);

BR——maximum bunkering rate agreed between ship and shore facility (m^3/h);

or 5 seconds, whichever is the least.

The bunkering rate is to be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant.

CHAPTER 14 OPERATION

Section 1 GENERAL PROVISIONS

14.1.1 Goal

14.1.1.1 The goal of this Chapter is to ensure that operational procedures for the loading, storage, operation, maintenance, and inspection of systems for natural gas fuels minimize the risk to personnel, the ship and the environment and that are consistent with practices for a conventional oil fuelled ship.

14.1.2 Functional requirements

14.1.2.1 This Chapter is related to functional requirements in 1.1.3.2, Chapter 1 of the Rules. In particular the following apply:

(1) maintenance procedures and information for all gas related installations are to be available on board;

(2) The ship is to be provided with operational procedures including a detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems; and

(3) The ship is to be provided with suitable emergency procedures.

Section 2 OPERATION

14.2.1 General requirements

14.2.1.1 Operations related to natural gas bunkering may refer to the relevant requirements of CCS Guidelines for LNG Fuel Bunkering Operation.

14.2.2 Maintenance

14.2.2.1 Maintenance and repair procedures are to include considerations with respect to the tank location and adjacent spaces in Chapter 2 of the Rules.

14.2.2.2 In-service survey, maintenance and testing of the fuel containment system are to be carried out in accordance with the inspection/survey plan required by 4.2.1.8, Chapter 4 of the Rules.

14.2.2.3 The procedures and information are to include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces are to be performed in accordance with a recognized standard①.

14.2.3 Responsibilities

14.2.3.1 Before any bunkering operation commences, the master of the receiving ship or his representative and the representative of the bunkering source (Persons In Charge, PIC) are to:

(1) agree in writing the transfer procedure, including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred;

① Refer to IEC 60079-17 Explosive atmospheres – Part 17: Electrical installations inspection and maintenance.

（2）agree in writing action to be taken in an emergency; and

（3）complete and sign the bunker safety check-list.

14.2.3.2 Upon completion of bunkering operation, the ship PIC is to receive and sign a Bunker Delivery Note for the fuel delivered, containing at least the information specified in Annex 3 of CCS Guidelines for LNG Fuel Bunkering Operation, completed and signed by the bunkering source PIC.

14.2.4 Fuel handling manuals

14.2.4.1 The fuel handling manual required by 14.1.2.1 (2) of this Section is to include but is not limited to:

（1）overall operation of the ship from dry-dock to dry-dock, including procedures for system cool down and warm up, bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing;

（2）bunker temperature and pressure control, alarm and safety systems;

（3）system limitations, cool down rates and maximum fuel storage tank temperatures prior to bunkering, including minimum fuel temperatures, maximum tank pressures, transfer rates, filling limits and sloshing limitations;

（4）operation of inert gas systems;

（5）firefighting and emergency procedures: operation and maintenance of firefighting systems and use of extinguishing agents;

（6）special equipment needed for the safe handling of the particular fuel;

（7）operation and maintenance of fixed and portable gas detection equipment;

（8）emergency shutdown and emergency release systems, where fitted; and

（9）a description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover.

（10）In addition, the manual for portable tanks are to at least include:

① tank securing, connecting and removal and other tank changing operation;

② fuel transfer from the tank in an emergency.

14.2.4.2 A fuel system schematic/piping and instrumentation diagram (P&ID) is to be reproduced and permanently displayed in the ship's bunker control station and at the bunker station.

14.2.5 Pre-bunkering verification

14.2.5.1 Prior to conducting bunkering operation, pre-bunkering verification including, but not limited to the following, is to be carried out and documented in the bunker safety checklist:

（1）all communications methods, including ship shore link (SSL), if fitted;

（2）operation of fixed gas and fire detection equipment;

（3）operation of portable gas detection equipment;

（4）operation of remote-controlled valves; and

（5）inspection of hoses and couplings.

14.2.5.2 Documentation of successful verification is to be indicated by the mutually agreed and executed bunkering safety checklist signed by both PIC's.

14.2.6 Ship bunkering source communications

14.2.6.1 Communications are to be maintained between the ship PIC and the bunkering source PIC at all times during the bunkering operation. In the event that communications cannot be maintained, bunkering is to stop and not resume until communications are restored.

14.2.6.2 Communication devices used in bunkering are to comply with recognized standards for such devices acceptable to CCS.

14.2.6.3 PIC's are to have direct and immediate communication with all personnel involved in the bunkering operation.

14.2.6.4 The SSL or equivalent means to a bunkering source provided for automatic ESD communications is to be compatible with the receiving ship and the delivering facility ESD system[①].

14.2.7 Electrical bonding

14.2.7.1 Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering are to be electrically continuous, suitably insulated and are to provide a level of safety compliant with recognized standards[②].

14.2.8 Conditions for transfer

14.2.8.1 Warning signs are to be posted at the access points to the bunkering area, listing fire safety precautions during fuel transfer.

14.2.8.2 During the transfer operation, personnel in the bunkering manifold area are to be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operation are to wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer is to cause to stop operation and transfer is not to be resumed until all required conditions are met.

14.2.8.3 Where bunkering is to take place via the installation of portable tanks, the procedure is to provide an equivalent level of safety as permanent tanks and systems. Portable tanks are to be filled prior to loading on board the ship and are to be properly secured prior to connection to the fuel system.

14.2.8.4 For tanks not permanently installed in the ship, the connection of all necessary tank systems (piping, controls, safety system, relief system, etc.) to the fuel system of the ship is part of the 'bunkering' process and is to be finished prior to ship departure from the bunkering source. Connecting and disconnecting of portable tanks during the sea voyage or manoeuvring is not permitted.

The control, monitoring and safety system of portable tanks required in 4.3.1.8 of the Rules is to be tested for the effectiveness of its each connection to the ship’s fuel system. The testing results are to be recorded and kept on board for information.

14.2.9 Enclosed space entry

14.2.9.1 Under normal operational circumstances, personnel is not to enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of an explosive atmosphere[③].

---

① Refer to ISO 28460, Ship-shore interface and port operation.

② Refer to API RP 2003 Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents and ISGOTT: International Safety Guide for Oil Tankers and Terminals.

③ Refer to the Revised recommendations for entering enclosed spaces aboard ships (A.1050(27)).

14.2.9.2 Personnel entering any space designated as a hazardous area is not to introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

14.2.10 Inerting and purging of fuel systems

14.2.10.1 The primary objective in inerting and purging of fuel systems is to prevent the formation of a combustible atmosphere in, near or around fuel system piping, tanks, equipment and adjacent spaces.

14.2.10.2 Procedures for inerting and purging of fuel systems are to ensure that air is not introduced into piping or a tank containing flammable gas atmosphere, and that gas is not introduced into air contained in enclosures or spaces adjacent to fuel systems.

14.2.11 Hot work on or near fuel systems

14.2.11.1 Hot work in the vicinity of fuel tanks, fuel piping and insulation systems that may be flammable, contaminated with hydrocarbons, or that may give off toxic fumes as a product of combustion is only to be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained.

CHAPTER 15 ADDITIONAL REQUIREMENTS FOR WORKING SHIPS WITH SEPARATED GAS SUPPLY

Section 1 GENERAL PROVISIONS

15.1.1 General requirements

15.1.1.1 This Chapter applies to inland waterways working ships supplied with LNG in a separate gas supply mode. A separate gas supply mode means a mode to supply gas to engines of a working ship by an offshore floating body, where fuel tanks, heat exchangers, control systems, valves and pipes etc. are installed (hereinafter referred to as Separate LNG Supply). The requirements of this Chapter are the basic principles. If necessary, a case evaluation may be required based on the actual operating conditions appropriate to types of ships.

15.1.1.2 The structures of the floating body are to comply with the requirements for the corresponding ship types of CCS Rules for the Construction of Inland Waterways Steel Ships.

15.1.1.3 Separate LNG Supply is only to be used during the supply operation of a floating body to a working ship after they are securely moored and anchored in a water, and is not to be permitted during the voyage of working ship.

15.1.1.4 For working ships with the separate supply, the floating body is to be considered as a means of attachment to the working ship, and is only to service to the corresponding working ships or their sister-ships. The plans and documents related to the working ship and floating body are to be submitted for approval.

Section 2 WORKING SHIPS AND OFFSHORE FLOATING BODIES

15.2.1 General requirements

15.2.1.1 The equipment numbers are to be separately calculated for working ships and floating bodies according to the relevant requirements of CCS Rules for the Construction of Inland Waterways Steel Ships, and effective mooring equipment are to be provided based on the sum of both the equipment numbers. The mooring equipment are to be so designed and arranged as to be appropriate to the operating mooring conditions in the water, taking into account excessive tensions acting on the lines due to the relative motions of the ship and changes in freeboard during operation. Mooring lines are to be made of synthetic fiber material.

15.2.1.2 Anchors and chains are to be provided based on the respective equipment numbers of the working ship and the floating body, and the floating body is to anchor at its side not for berthing. Gas supply is only permitted at anchor.

15.2.1.3 The floating body is to be provided with steel fenders, such as insert plates or other equivalent means, along its berthing side. The fenders are to be continuously arranged along the deck at side, with rubber gaskets or equivalent materials fitted on their surfaces to prevent sparks due to the ship's friction. The fenders are to to insulated to the working ship.

15.2.1.4 An access dedicated for personnel passage of at least 850 mm in width is to be fitted between the floating body and the working ship, and life-saving appliances are to be provided according to the maximum number of operating personnel on the floating body. Non-operating personnel is not permitted on the floating body.

15.2.1.5 Except for the hazardous area at the connection of the floating body to the working ship, other hazardous areas are not to extend beyond the shell plating of each.

15.2.1.6 Fire-extinguishing appliances are to be fitted on the working ship or on the floating body to effectively extinguish a fire on the floating body. The carriage of such appliances is to be not less than that required in CCS Rules for Liquefied Natural Gas Bunkering Pontoons.

15.2.1.7 The power distribution systems, main sources of electrical power and lighting on board the floating body are to be equipped according to CCS Rules for Liquefied Natural Gas Bunkering Pontoons.

15.2.1.8 Lightning, static electricity and stray current protection for the floating body are to be comply with CCS Rules for Liquefied Natural Gas Bunkering Pontoons.

Section 3 FUEL TANKS AND GAS SUPPLY SYSTEMS

15.3.1 General requirements

15.3.1.1 Hull structures within the area for installing fuel tanks are to be suitably strengthened, and a finite element analysis is to be required to assess the strength of the connection of the tank seat to the hull structure of the floating body. The structural models, boundary conditions and loading conditions considered in the finite element analysis are to comply with CCS Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk.

15.3.1.2 Fuel tanks and gas supply systems etc. are to be installed on open deck, their distances to the shell plating of the floating body are to comply with the relevant requirements of the Rules, and conspicuous warning signs are to be provided on the floating body.

15.3.1.3 A tank connection space is to be fitted where tank connections, flanges, valves and other fittings are enclosed.

15.3.1.4 Protective structures are to be provided to protect the tanks and their fittings and piping to prevent damage during the operation of the working ship.

15.3.1.5 Hoses are to be provided for the connection of the floating body to the working ship, and the hoses are to comply with CCS Rules for Liquefied Natural Gas Bunkering Pontoons. Means are to be provided on the connecting pipes of gas supply lines for gas-freeing and inerting.

15.3.1.6 All emergency stop valves of the floating body are to be effectively controlled from the working ship, and the tank master gas valve of the floating body is to automatic shutdown after disconnecting the ships.

15.3.1.7 A connecting hose of gas supply line is to be provided with a breakaway coupling complying with CCS Rules for Liquefied Natural Gas Bunkering Pontoons, to ensure that its disconnection will not release a vast amount of flammable gas in an emergency. The breakaway couplings are to be protected by suitable supporting to prevent fatigue damage due to the relative motions of the ships.

15.3.1.8 The pipes and components of the floating body isolating liquefied gas are to be provided with pressure relief valves. Outlets of all pressure relief valves and outlets of other pipes which may contain natural gas are to be connected to vent headers, and vent headers are to arranged according to the relevant requirements of the Rules.

15.3.1.9 All monitoring and control of fuel tanks and gas supply systems are to refer to the relevant requirements of the Rules, and to be displayed and operated both on the floating body and the working ship.

15.3.1.10 Where fuel tanks are located on the open deck of the floating body, the boundaries of accommodation spaces, service spaces, cargo spaces, machinery spaces and control stations on the working ship facing the fuel tanks, are to be shielded by A-60 class divisions. The A-60 class divisions are to extend up to the underside of the deck of the navigation bridge or up to the top of the bulkhead.

ANNEX 1 RISK ASSESSMENT

Section 1 GENERAL PROVISIONS

1.1 **General requirements**

1.1.1 This Annex applies to bunkering, storage, supply and using of LNG.

1.1.2 The risk assessment may be a quantitative, semi-quantitative or quantitative approach, and the approach used is to be approved by CCS.

Section 2 RISK ASSESSMENT FACTORS

2.1 Risk assessment procedure

2.1.1 The risk assessment is to at least include:

(1) preparation;

(2) information and data collection;

(3) hazard identification;

(4) leakage scenario definition;

(5) failure frequency analysis;

(6) impact analysis;

(7) risk calculation;

(8) risk assessment;

(9) proposal for risk reducing measures.

2.2 Leakage scenarios

2.2.1 Hazard identification is to be carried out with a systematic and comprehensive method, such as preliminary hazard analysis (PHA), 'what-if' analysis, hazard operability (HAZOP) analysis, failure modes and effects analysis (FMEA), fault tree analysis (FTA) and event tree analysis (ETA). Hazard identification may use but not limited to the guidewords in Appendix 1 of this annex.

2.2.2 Leakage scenarios are to be determined taking into account leakage rates, time durations and amount of leakage of liquefied, gaseous or liquid-gas two-phase natural gas.

2.2.3 Consideration is to be given to thermal properties and physical characteristics of LNG exposed to environment, harmful actions due to interaction with the ship’s structures, equipment and the surface of water, including but not limited to vapour cloud diffusion, flash fire, pool fire and explosion.

2.2.4 The matrix used for the leakage scenarios analysis may use but not limited to those listed in Appendix 2 of this annex.

2.3 Failure frequency analysis

2.3.1 The following data sources may be used:

(1) failure database appropriate to the LNG industry;

(2) historical statistics of enterprises;

(3) failure mode based on reliability;

(4) values proposed in Appendix 3;

(5) other data sources.

2.3.2 The failure data used is to be ensured to be consistent with basic inherent assumptions of leakage scenarios, taking into account the influence of the ship safety management level on the probability of scenario occurrence, and amendments may be made by means of Standard SY/T 6714 or API 581.

2.3.3 In calculation of the frequency of leakage of equipment, full consideration is to be given to the probability of various weather and other environmental parameters, including wind speed, wind direction, atmospheric temperature, relative humidity of atmosphere and temperature of the substrate.

2.3.4 Consideration is to be given to ship arrangement and structures in hazard evaluation, including all factors which may affect the diffusion path of liquid or gas leakage.

2.3.5 ETA is to be built with instantaneous ignition, delayed ignition and unignited probabilities after leakage.

2.3.6 The probability of death is to be determined by means of an efficient calculation method or from a recognized database.

2.3.7 If the probability of occurrence of a leakage scenario is less than 10-8 per year or the probability of death caused by an accident scenario is less than 1%, this scenario may not be taken into consideration in quantitative risk assessment (QRA).

2.4 Impact analysis

2.4.1 An analytical model or software approved by CCS (CFD is recommended) is to be used to calculate the impact of consequences, normally including at least the following categories of hazards and extents of damage:

(1) intensity of thermal radiation from a fire;

(2) concentration of vapour cloud diffusion;

(3) shock wave pressure from explosion.

2.4.2 The impact analysis may use the acceptance criteria other than those listed in this annex provided they are approved by CCS.

2.4.3 The acceptance criteria of thermal flux and thermal dose of thermal radiation from a pool fire are to comply with Table 2.4.3 of this Annex.

The Acceptance Criteria of Thermal Radiation Table 2.4.3

	Maximum intensity of thermal radiation （kW/m^2）	Maximum thermal dose of thermal radiation$[kW/m^2]^{4/3}t$	Comments
Fire	5.0	500	In the event of not less than 10% of skin exposure to a fire for 30 seconds, second-degree burns to at least 10 persons.
	5.0	300	In the event of not less than 10% of skin exposure to a fire for 30 seconds, second-degree burns to at least one person in the building.

	32	N/A	Loss of strength (significantly decreased loading capacity)of steel structures exposure to a fire during sustained burning.

2.4.4 The acceptance criteria of volumetric concentration of vapour cloud diffusion is to comply with Table 2.4.4 of this annex.

The Acceptance Criteria of Volumetric Concentration of Vapour Cloud Diffusion Table 2.4.4

Vapour cloud diffusion	Volumetric concentration	Comments
	2.5%	50% of lower flammable limit of methane

2.4.5 The acceptance criteria of shock wave pressure from explosion is to comply with Table 2.4.5 of this annex.

The Acceptance Criteria of Shock Wave Pressure from Explosion Table 2.4.5

Explosion	Overpressure corresponding to damage（N/m^2）		Categories of overpressure damage
	Lower limit	Upper limit	
	250	4000	Damage at window panes
	5000	10000	Damage at doors and covers and personal injury
	15000	20000	Serious structural damage
	25000	50000	Serious casualties

Section 3 RISK CRITERIA

3.1 Definitions

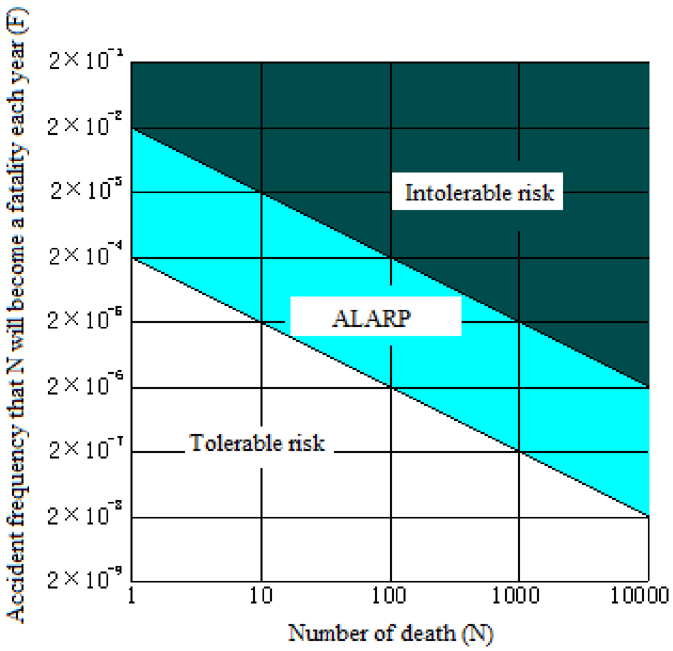
3.1.1 An individual risk is a probability that an individual is exposed to hazards in a hazardous area, which normally means the probability that an individual will become a fatality each year. The acceptance criteria of individual risk is to comply with Table 3.1.1 of this Annex.

3.1.2 A social risk is a probability that a group of persons (including employees and the public) is exposed to hazards during a defined period of time, which in general means the accident accumulation frequency that greater than or equal to N persons will become a fatality each year, and is shown in a curve of accumulation frequency and number of death (a F-N curve). The acceptance criteria of social risk is to comply with Figure 3.1.2 of this annex.

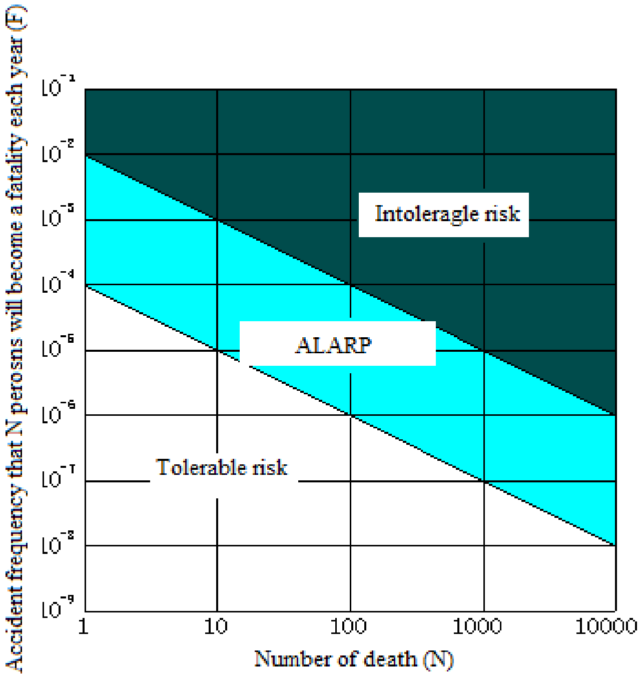
The Individual Risk (IR) Acceptance Criteria Table 3.1.1

	Value-at-risk (frequency of death/ship/year)

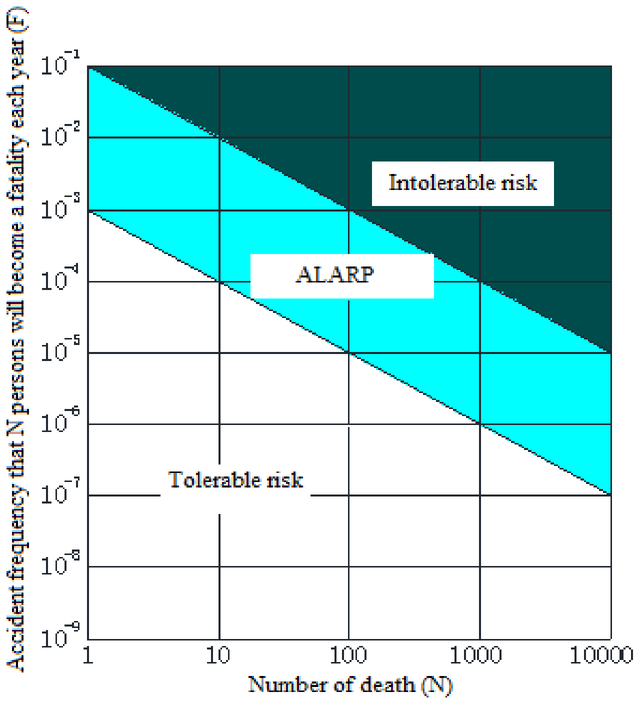
	Existing ship	New ship
Maximum risk acceptable to crew	1.0E-3	1.0E-4
Maximum risk acceptable to passengers on board or persons on shore	1.0E-4	1.0E-5
Important objectives, such as major engineering areas (e.g. Three Gorges ship lock) , military administrative zones and heritage protected areas	3.0E-7	3.0E-7
Widely accepted risk (other than important objectives)	1.0E-6	1.0E-6



a) Social risk (SR) acceptability criteria for oil tanker and chemical tanker



b) Social risk (SR) acceptability criteria for bulk carrier, container ship and ro-ro ship



c) Social risk (SR) acceptability criteria for passenger ship

Figure 3.1.2 The Social Risk (SR) Acceptance Criteria

Section 4 RISK MITIGATIONS

4.1 General requirements

4.1.1 Where the risk calculated is just on the border of the area of intolerable risk or ALARP, additional mitigation actions are to be carried out to reduce the risk to be tolerated.

4.1.2 The mitigation actions include but do not limited to new technologies and instruments combined in the design, optimized design of installation arrangement, upgrades of equipment, improving leakage alarm devices, emergency response procedures and operation procedures.

4.1.3 The mitigation actions used are to be approved by CCS.

Appendix 1

PROMPTS - GUIDEWORDS AND PHRASES

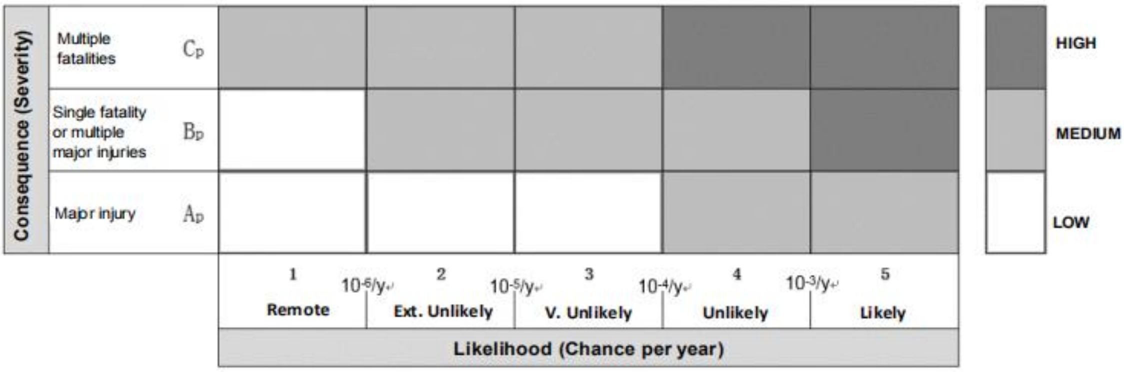
Example prompts for use in QualRA

Failure of fuel containing equipment* – a hole/crack leading to release of fuel	
Wear and tear	Vibration, loading, cycling, prolonged use
Erosion	Fuel contaminants, high stream velocity, prolonged use
Stress and strain	Vibration, loading, cycling, ship movement, prolonged use
Fatigue	Vibration, loading, cycling, ship movement, prolonged use
Corrosion	Exposure to weather, exposure to sea water, humidity, loss of dry air supply, contact with corrosive materials
Collision	Ship collides with another vessel, ship hits rocks, ship strikes the harbour wall or jetty
Grounding	Ship runs aground
Impact	Dropped object (e.g. during maintenance or cargo loading), collapse of supporting structure, maloperation during loading/maintenance
Fire	Ignition of flammable materials, fire in adjacent spaces/areas
* Plus equipment containing gases or other substances that could release into spaces resulting in harm (e.g. asphyxiation, burns)	
Failure of control procedures —— operation beyond design conditions and subsequent fuel leakage	
Temperature high	Loss of insulation, instrument failure, software failure, actuator failure, maloperation by operator, external fire, exposure to extreme weather, decomposition
Temperature low	Loss of heating medium circulation, heating medium contamination, instrument failure, software failure, actuator failure, maloperation by operator, exposure to extreme weather
Pressure high	Maloperation by operator (e.g. closed valve), loss of utilities (e.g. instrument air), external fire, loss of power supply, rollover, excess generation of boil-off gas, actuator failure
Pressure low (vacuum)	Maloperation by operator, loss of utilities (e.g. instrument air), loss of power supply (electricity), actuator failure
Flow high	Instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Flow low	Instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Flow reversed	Instrument failure, software failure, maloperation by operator (e.g. closed valve), exposure to extreme sea conditions
No Flow	Instrument failure, software failure, maloperation by operator (e.g. closed valve), actuator failure
Level high	Instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Level low	Instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions

Fuel left in pipe/line	Maloperation by operator, closed valves, no inert/purge supply, limited inert/purge supply
No fuel in pipe/line	Instrument failure, software failure, maloperation by operator, closed valves
Loss of power	Loss of electrical signals, blackout, loss of instrument air, loss of hydraulic fluid

Appendix 2

RISK MATRIX EXAMPLE – PERSONS ON BOARD



Consequence Category Examples

A_P: Major injury - long-term disability / health effect

B_P: Single fatality or multiple major injuries - one death or multiple individuals suffering long-term disability / health effects

C_P: Multiple fatalities - two or more deaths

Likelihood Category Examples

1. Remote - 1 in a million or less per year
2. Extremely Unlikely - between 1 in a million and 1 in 100,000 per year
3. Very Unlikely - between 1 in 100,000 and 1 in 10,000 per year
4. Unlikely - between 1 in 10,000 and 1 in 1,000 per year
5. Likely - between 1 in 1,000 and 1 in 100 per year

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. 25×10^{-6}).

Risk Rating and Risk Criteria Examples

Low Risk——A_P1, A_P2, A_P3 and B_P1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

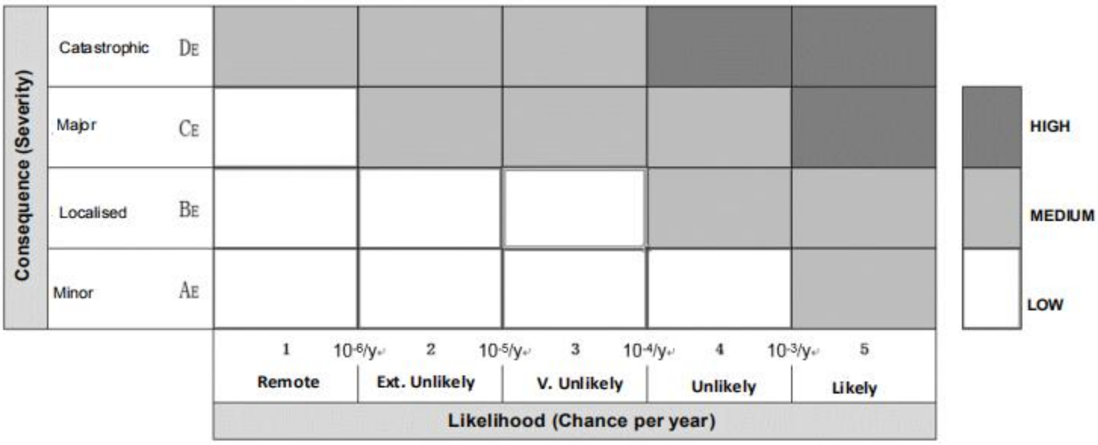
Medium Risk——A_P4, A_P5, B_P2, B_P3, B_P4, C_P1, C_P2 and C_P3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk——B_P5, C_P4 and C_P5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Risk Matrix Example – environment



Consequence Category Examples

A_E: Minor - limited and reversible damage to sensitive areas/species in the immediate vicinity;

B_E: Localised - significant but reversible damage to sensitive areas/species in the immediate vicinity;

C_E: Major - extensive or persistent damage to sensitive areas/species;

D_E: Catastrophic - irreversible or chronic damage to sensitive areas/species;

Likelihood Category Examples

1.Remote - 1 in a million or less per year

2.Extremely Unlikely - between 1 in a million and 1 in 100,000 per year

3.Very Unlikely - between 1 in 100,000 and 1 in 10,000 per year

4.Unlikely - between 1 in 10,000 and 1 in 1,000 per year

5.Likely - between 1 in 1,000 and 1 in 100 per year

For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship’s lifetime is 1 in 40000 (i.e. 25×10^{-6}).

Risk Rating and Risk Criteria Examples

Low Risk——A_E1, A_E2, A_E3, A_E4, B_E1, B_E2, B_E3 and C_E1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective, it is good practice to implement mitigation measures that would further reduce the risk.

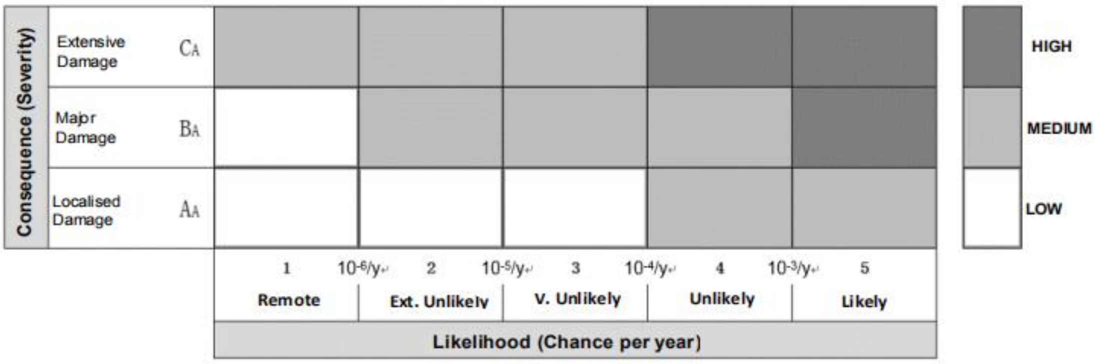
Medium Risk——A_E5, B_E4, B_E5, C_E2, C_E3, C_E4, D_E1, D_E2 and D_E3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk ——C_E5, D_E4 and D_E5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Risk Matrix Example – ship assets (equipment, spaces and structures)



Consequence Category Examples

A_A: Localised damage - an event halting operation for more than x days

B_A: Major damage - an event halting operation for more than y days

C_A: Extensive damage - loss of ship, an event halting operation for more than z days

Likelihood Category Examples

1.Remote - 1 in a million or less per year

2.Extremely Unlikely - between 1 in a million and 1 in 100,000 per year

3.Very Unlikely - between 1 in 100,000 and 1 in 10,000 per year

4.Unlikely - between 1 in 10,000 and 1 in 1,000 per year

5.Likely - between 1 in 1,000 and 1 in 100 per year

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40000 (i.e. 25×10^{-6}).

Risk Rating and Risk Criteria Examples

Low Risk—— AA1, AA2, AA3 and BA1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective, it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk——A_A4, A_A5, B_A2, B_A3, B_A4, C_A1, C_A2 and C_A3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk—— B_A5, C_A4 and C_A5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Appendix 3

Failure frequency

Failure frequency - Likelihood Category

1. Remote - 1 in a million or less per year (10^{-6}/y or less)			
Type C independent tank	<1 x 10^{-6}		
2. Extremely Unlikely - between 1 in a million and 1 in 100,000 per year (10^{-6}/y to 10^{-5}/y)			
Leakage aperture (diameter)	**≤50 mm**	**51 mm ~150 mm**	**151 mm ~300 mm**
Pipe/per meter	7 x 10^{-6}	3 x 10^{-6}	3 x 10^{-6}
Flange	4 x 10^{-6}	5 x 10^{-6}	7 x 10^{-6}
Manual valve	---	7 x 10^{-6}	9 x 10^{-6}
3. Extremely Unlikely - between 1 in 100,000 and 1 in 10,000 per year (10^{-5}/y to 10^{-4}/y)			
Leakage aperture	**≤50 mm**	**51 mm ~150 mm**	**151 mm ~300 mm**
Pipe/per meter	8 x 10^{-5}	4 x 10^{-5}	3 x 10^{-5}
Flange	4 x 10^{-5}	5 x 10^{-5}	8 x 10^{-5}
Manual valve	3 x 10^{-5}	5 x 10^{-5}	7 x 10^{-5}
4. Extremely Unlikely - between 1 in 10,000 and 1 in 1,000 per year (10^{-4}/y to 10^{-3}/y)			
Leakage aperture	**≤50 mm**	**51 mm ~150 mm**	**151 mm ~300 mm**
Control valve	3 x 10^{-4}	3 x 10^{-4}	3 x 10^{-4}
Connecting arrangement	3 x 10^{-4} including flanges		
Process vessel	7 x 10^{-4} pressure vessel		
5. Extremely Unlikely - between 1 in 1,000 and 1 in 100 per year (10^{-3}/y to 10^{-2}/y)			
Leakage aperture		**51 mm ~150 mm**	**151 mm ~300 mm**
Heat exchanger / vaporizer / heater		2 x 10^{-3}	2 x 10^{-3}
Bump (centrifugal type or reciprocating type)		5 x 10^{-3}	1 x 10^{-3}

ANNEX 2 STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF FUEL CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

Section 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 The purpose of this Annex is to provide procedures and relevant design parameters of limit state design of fuel containment systems of a novel configuration according to 4.2.17 of Chapter 4 of the Rules.

1.1.2 Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 4.2.1.6 of Chapter 4 of the Rules. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the Rules.

1.1.3 The limit states are divided into three categories:

(1) Ultimate Limit States (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse; under intact (undamaged) conditions;

(2) Fatigue Limit States (FLS), which correspond to degradation due to the effect of cyclic loading; and

(3) Accident Limit States (ALS), which concern the ability of the structure to resist accident situations.

1.1.4 The relevant requirements of 4.2.1 to 4.2.12 of Chapter 4 of the Rules are to be complied with as applicable according to the fuel containment system concept.

Section 2 DESIGN FORMAT

2.1 General requirements

2.1.1 The design format in this Annex is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, L_d, do not exceed design resistances, R_d , for any of the considered failure modes in any scenario:

$$L_d \leq R_d$$

2.1.2 A design load F_{dk} is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f F_k$$

where: γ_f—— load factor; and

F_k—— the characteristic load as specified in 4.2.7 to 4.2.9 of Chapter 4 of the Rules.

2.1.3 A design load effect L_d (e.g. stresses, strains, displacements and vibrations) is the most unfavourable combined load effect derived from the design loads, and may be expressed by:

$$L_d = q(F_{d1}, F_{d2}, \ldots, F_{dN})$$

where: q—— functional relationship between load and load effect determined by structural analyses.

2.1.4 The design resistance R_d is determined as follows:

$$R_d = \frac{R_k}{\gamma_R \gamma_C}$$

where: R_k—— the characteristic resistance. In case of materials involved in Chapter 3 of the Rules, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;

γ_R——the resistance factor, $\gamma_R = \gamma_m \cdot \gamma_s$;

γ_m——the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);

γ_s——the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis; and

γ_C——the consequence class factor, which accounts for the potential results of failure with regard to release of fuel and possible human injury.

2.2 Failure consequences

2.2.1 Fuel containment design is to take into account potential failure consequences. Consequence classes are defined in Table 2.2.1 of this Annex, to specify the consequences of failure when the mode of failure is related to the Ultimate Limit State, the Fatigue Limit State, or the Accident Limit State.

Consequence classes **Table 2.2.1**

Consequence classes	Definitions
Low	Failure implies minor release of the fuel.
Medium	Failure implies release of the fuel and potential for human injury.
High	Failure implies significant release of the fuel and high potential for human injury/fatality.

Section 3 REQUIRED ANALYSES

3.1 General requirements

3.1.1 Three-dimensional finite element analyses are to be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes are to be identified to avoid unexpected failures. Hydrodynamic analyses are to be carried out to determine the particular ship accelerations and motions in irregular waves, and the response of the ship and its fuel containment systems to these forces and motions.

3.1.2 Buckling strength analyses of fuel tanks subject to external pressure and other loads causing compressive stresses are to be carried out in accordance with recognized standards. The method is adequately to account for the difference in theoretical and actual buckling stress as a result of plate out of flatness, plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.

3.1.3 Fatigue and crack propagation analysis is to be carried out according to 5.1 of this Annex.

Section 4 ULTIMATE LIMIT STATES

4.1 General requirements

4.1.1 Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength are to be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance (dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities).

4.1.2 Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads are to be considered in the analysis. At least two load combinations with partial load factors as given in Table 4.1.2 of this Annex are to be used for the assessment of the ultimate limit states.

Partial load factors **Table 4.1.2**

Load combination	Permanent loads	Functional loads	Environmental loads
‘a’	1.1	1.1	0.7
‘b’	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination 'a' are relevant for the normally well-controlled and/or specified loads applicable to fuel containment systems such as vapour pressure, fuel weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.

4.1.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by CCS.

4.1.4 In cases where structural failure of the fuel containment system are considered to imply high potential for human injury and significant release of fuel, the consequence class factor is to be taken as γ_C =1.2. This value may be reduced if it is justified through risk analysis and approved by CCS. The risk analysis is to take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended fuel. Conversely, higher values may be fixed by CCS, for example, for ships carrying more hazardous or higher pressure fuel. The consequence class factor is in any case not to be less than 1.0.

4.1.5 The load factors and the resistance factors used are to be such that the level of safety is equivalent to that of the fuel containment systems as described in 4.2.2.1 to 4.2.2.6 of Chapter 4 of the Rules. This may be carried out by calibrating the factors against known successful designs.

4.1.6 The material factor γ_m is in general to reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in Chapter 4 of the Rules, the material factor γ_m may be taken as:

γ_m=1.1, when the characteristic mechanical properties specified by CCS typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or

γ_m=1.0, when the characteristic mechanical properties specified by CCS represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.1.7 The partial resistance factors γ_{si} is in general to be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

4.1.8 For design against excessive plastic deformation using the limit state criteria given in 4.8 of this Annex, the partial resistance factors γ_{si} is to be taken as follows:

$$\gamma_{s1} = 0.76\frac{B}{k_1}$$

$$\gamma_{s2} = 0.76\frac{D}{k_2}$$

$$k_1 = \mathrm{Min}\left(\frac{R_m}{R_e}\cdot\frac{B}{A};1.0\right)$$

$$k_2 = \mathrm{Min}\left(\frac{R_m}{R_e}\cdot\frac{D}{C};1.0\right)$$

Factors A, B, C and D are defined in 4.2.14.3 of Chapter 4 of the Rules. R_m and R_e are defined in 4.2.10.1 (4) of Chapter 4 of the Rules.

The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

4.2 Design against excessive plastic deformation

4.2.1 Stress acceptance criteria given below refer to elastic stress analyses.

4.2.2 Parts of fuel containment systems where loads are primarily carried by membrane response in the structure are to satisfy the following limit state criteria:

$\sigma_m \leq f$

$\sigma_L \leq 1.5f$

$\sigma_b \leq 1.5F$

$\sigma_L + \sigma_b \leq 1.5F$

$\sigma_m + \sigma_b \leq 1.5F$

$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$

$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$

where:

σ_m= equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

σ_g= equivalent secondary stress

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

With regard to the stresses σ_m, σ_L, σ_b and σ_g see also the definition of stress categories in 4.2.14.7 of Chapter 4 of the Rules.

Guidance Note:

The stress summation described above is to be carried out by summing up each stress component (σ_x, σ_y, τ_{xy}), and subsequently the equivalent stress is to be calculated based on the resulting stress components as shown below.

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}$$

4.2.3 Parts of fuel containment systems where loads are primarily carried by bending of girders, stiffeners and plates, are to satisfy the following limit state criteria:

$\sigma_{ms} + \sigma_{bp} \leq 1.25F$ (See Note 1 and Note 2)

$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F$ (See Note 2)

$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \leq 3.0F$

Note 1: The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

Note 2: The coefficient 1.25, may be modified by CCS considering the design concept, configuration of structure, and the methodologies used for the stress calculation.

where:

σ_{ms} = equivalent section membrane stress in primary structure;

σ_{bp} = equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure;

σ_{bs}= section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure;

σ_{bt} = section bending stress in tertiary structure;

σ_g = equivalent secondary stress.

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

The stresses σ_{ms}, σ_{bp}, σ_{bs}, and σ_{bt} are defined in 4.3 of this Annex, and σ_g is defined in 4.2.14.7 of Chapter 4 of the Rules.

Guidance Note:
The stress summation described above is to be carried out by summing up each stress component (σ_x, σ_y, τ_{xy}), and subsequently the equivalent stress is to be calculated based on the resulting stress components.

4.2.4 Skin plates are to be designed in accordance with the requirements of CCS. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity is to be appropriately considered in addition.

4.3 Section stress categories

4.3.1 Normal stress is the component of stress normal to the plane of reference.

4.3.2 Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in 4.2.2 of this Annex.

4.3.3 Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action, as shown in Figure 4.3.

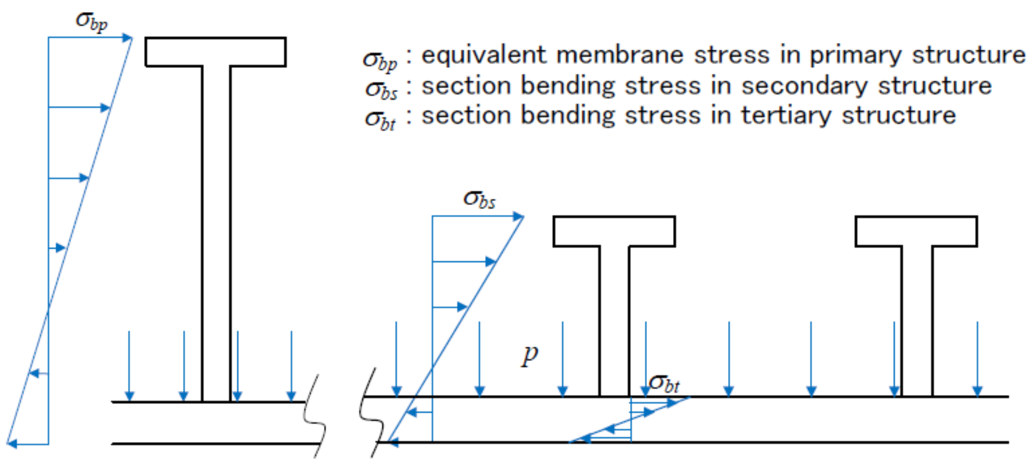


Figure 4.3 The Definition of Three Section Stresses

(Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.3.4 The same factors γ_C, γ_m, γ_{si} are to be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case, the overall level of safety is not to be less than given by these factors.

Section 5 FATIGUE LIMIT STATES

5.1 General requirements

5.1.1 Fuel containment systems are to be compliance with the fatigue design condition as described in 4.2.10.2 of Chapter 4 of the Rules, as applicable, according to the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under 4.2.17 of Chapter 4 of the Rules and this Annex.

5.1.2 The load factors for *FLS* is to be taken as 1.0 for all load categories.

5.1.3 Consequence class factor γ_C and resistance factor γ_R are to be taken as 1.0.

5.1.4 Fatigue damage is to be calculated according to 4.2.10.2 (2) to 4.2.10.2 (5) of Chapter 4 of the Rules. The calculated cumulative fatigue damage ratio for the fuel containment systems is not to be greater than the values given in Table 5.1.4 of this Annex.

Maximum allowable cumulative fatigue damage ratio Table 5.1.4

	Consequence classes		
	Low	Medium	High
C_W	1.0	0.5	0.5*

Note *: Lower values are to be used in accordance with 4.2.10.2 (12) to 4.2.10.2 (14) of Chapter 4 of the Rules, depending on the detectability of defect or crack. Lower values may be fixed by CCS.

5.1.5 Crack propagation analysis is to be calculated as described in 4.2.10.2 (7) to 4.2.10.2 (14) of Chapter 4 of the Rules. The analysis is to be carried out in accordance with the methods laid down in a standard recognized by CCS.

Section 6 ACCIDENT LIMIT STATES

6.1 General requirements

6.1.1 Fuel containment systems are to comply with the accident design condition as described in 4.2.10.3 of Chapter 4 of the Rules, as applicable, depending on the fuel containment system concept.

6.1.2 Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario.

6.1.3 The load factors for ALS are to be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.1.4 Loads mentioned in 4.2.7.3 (3)⑧ and 4.2.7.5 of Chapter 4 of the Rules need not be combined with each other or with environmental loads as defined in 4.2.7.4 of Chapter 4 of the Rules.

6.1.5 Resistance factor γ_R is in general to be taken as 1.0.

6.1.6 Consequence class factors γ_C are normally to be taken as defined in 4.1.4 of this annex, but may be relaxed considering the nature of the accident scenario.

6.1.7 The characteristic resistance R_k is in general to be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.1.8 Relevant additional accident scenarios are to be determined based on the risk analysis.

Section 7 TESTING

7.1 General requirements

7.1.1 Fuel containment systems designed according to this Annex are be tested to the same extent as described in Section 2, Chapter 13 of the Rules, as applicable depending on the fuel containment system concept concept.

ANNEX 3 STRENGTH ASSESSMENT OF FUEL TANK STRUCTURES OF SEA-GOING SHIPS

Section 1 GENERAL PROVISIONS

1.1 General Requirements

1.1.1 This Annex applies to ships for transport on seas using LNG as fuel, such as oil tankers, chemical tankers, container ships, bulk carriers, ore carriers and ro-ro ships. Other LNG-powered seagoing ships may also refer to the applicable section of this Annex for strength assessment of the fuel tank structures.

1.1.2 Strength assessment of fuel tank structures are to be based on generally accepted principles of statics, dynamics and material strength. Structural strength may be determined by testing, simplified linear elastic analysis, elastoplastic analysis or the finite element method for cargo hold assessment specified in this Annex.

1.1.3 Strength assessment of hull structures and support structures in the fuel tank area is to take into account the design loads specified in 4.2.7 of Chapter 4 of the Rules.

1.1.4 The range to be considered for design loads depends on the type of fuel tanks. For seagoing ships with type C independent fuel tanks, the relevant requirements in Section 2 of this Annex are to be complied with. For seagoing ships with type A/B independent fuel tanks, the relevant requirements in Section 3 of this Annex are to be complied with. For seagoing ships with membrane type fuel tanks, the relevant requirements in Section 4 of this Annex are to be complied with.

1.1.5 Strength assessment is to be carried out for the following structures:

(1) Independent fuel tank boundary and internal plating structures;

(2) Independent fuel tank supporting structure and anti-flotation arrangement (if any);

(3) Primary members of hull structures supporting the independent fuel tank and anti-flotation arrangement (if any);

(4) Membrane type fuel tank boundary and its primary supporting members.

1.1.6 Corrosion deduction in the structural model is to be in accordance with the requirements of the applicable rules for each ship type. For independent fuel tank structures, corrosion addition usually does not need to be considered.

1.1.7 The finite element model is as least to cover the complete fuel tank structure area.

Section 2 TYPE C INDEPENDENT FUEL TANK

2.1 General Requirements

2.1.1 The design of type C independent fuel tank and its containment system is to meet the relevant requirements of 4.2.15 of Chapter 4 of the Rules.

2.1.2 The scantlings of the type C independent fuel tank structure are given in the applicable requirements of Section 3 of Appendix 2 of Chapter A4 of PART TWO in the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Strength verification is to be carried out by direct calculation in accordance with Section 5 of Appendix 2 for the hull in way of the connecting area of the fuel tank and its supporting structures, other local areas with high stress level (e.g. Y-shape connection in bi-lobe and Star-Tri-Cylinder or called as tri-lobe tank) and attachments of cargo tanks (e.g. stiffening rings, bulkheads etc.).

2.1.3 Type C independent fuel tank saddles together with the supporting structures are to be subject to strength assessment. Where the saddle is connected with the hull structure directly, relevant requirements of Section 4 of Appendix 2 of Chapter A4 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with. Where the saddle is connected with the type C independent fuel tank directly, relevant requirements of Section 5 of Appendix 2 of Chapter A4 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with.

2.2 Bulk carriers and ore carriers

2.2.1 Load conditions

2.2.1.1 Design loads for direct calculation include local loads such as hull girder loads, cargo loads, fuel tank internal pressure (including static and dynamic liquid pressure and vapor pressure of fuel tank), ballast water loads, external sea pressure together with the self-weight of the hull and fuel tank.

2.2.1.2 Taking the main hull tank in way of the center of gravity of the type C independent fuel tank as the target tank, the loads of hull girder include:

(1) still water load, including still water bending moment and still water shear force, while still water bending moment (sagging and hogging) and still water shear force are to be taken as the maximum (or minimum) permissible value of the targeted tank;

(2) For CSR bulk carriers, the hull girder wave load includes vertical wave bending moment, vertical wave shear force, horizontal wave bending moment and wave torque. According to Section 2 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships, the target value of hull girder wave load is to be determined according to the dynamic load combination factors (LCF) corresponding to different equivalent design waves.

(3) For non-CSR bulk carriers, the hull girder wave load includes vertical wave bending moment, which is to be calculated according to 1.5.6.1(2) of Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(4) For ore carrier, the hull girder wave load includes vertical wave bending moment, vertical wave shear force, horizontal wave bending moment and wave torque. According to Section 2 of Chapter 4 of CCS Rules for Structures of Ore Carriers, the target value of hull girder wave load is to be determined according to the dynamic load combination factors (LCF) corresponding to different equivalent design waves.

2.2.1.3 The weight of hull and independent tank is to be considered in calculation and the effect may be taken into account by setting the material density of element in the finite element model and acceleration field (including acceleration of gravity).

2.2.1.4 External pressure, including static pressure of sea water and wave pressure, is to be calculated as follows:

(1) For CSR bulk carriers, calculation is to be in accordance with Section 5 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, calculation is to be in accordance with Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(3) For ore carriers, calculation is to be in accordance with Section 5 of Chapter 4 of CCS Rules for Structures of Ore Carriers.

2.2.1.5 Internal pressure is to be calculated separately for each load condition. Internal pressure includes static pressure of cargo, ballast water, fuel oil and LNG fuel and their dynamic pressure due to acceleration, and pressure relief valve set pressure. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

(1) For CSR bulk carriers, except for the fuel tank load, other loads are to be calculated according to Section 6 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

(2) For non-CSR bulk carriers, except for the fuel tank load, other loads are to be calculated according to Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) For ore carriers, except for the fuel tank load, other loads are to be calculated in accordance with Section 6 of Chapter 4 of CCS Rules for Structures of Ore Carriers.

2.2.1.6 Internal dynamic pressure of the fuel tank is to be calculated according to 4.28.1.2 of Chapter 4 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For different sea-going conditions, combined calculation is to be carried out by multiplying a factor specified below with the acceleration component given in 4.28.2 of Chapter 4 of PART THREE. The values of acceleration(a_x, a_y, a_z) used in the calculation are shown in the attached tables 1.2.1, 1.2.2 and 1.2.3 for collision condition, static heeling condition and flooding and anti-flotation condition. Acceleration factors (k_x, k_y, k_z) under various different sea-going conditions are calculated as follows:

(1) For CSR bulk carriers, the acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. See Section 3 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships for details. The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations (a_{x-env}, a_{y-env}, a_{z-env}) at the center of gravity of the tank. The acceleration factor in each direction is to be taken as 1.0 if it exceeds 1.0;

(2) For non-CSR bulk carriers, only vertical acceleration factor k_z is considered in sea-going conditions, and the value of acceleration factor is shown in Table 1.2.1.

(3) For ore carriers, the acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Section 2 of Chapter 4 of CCS Rules for Structures of Ore Carriers. For details, see Section 3 of Chapter 4 of CCS Rules for Structures of Ore Carriers. The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations ($a_{x\text{-}env}, a_{y\text{-}env}, a_{z\text{-}env}$) at the center of gravity of the tank. The acceleration factor in each direction is to be taken as 1.0 if it exceeds 1.0;

2.2.1.7 Typical loading modes are to be considered in calculation of conditions, including the following special conditions:

(1) In the collision condition where fuel tank has the inertial force corresponding to 0.5*g* in the forward direction and the inertial force corresponding to 0.25*g* in the backward direction, only static load is considered for the external sea pressure and hull girder load in the collision condition, and only static liquid pressure is considered for the tank pressure inside the fuel tank ;

(2) In the static heeling condition, the change of external sea pressure and tank pressure due to inclination under heeling of 30° is considered, without considering the wave load;

(3) Under the flooding and anti-flotation condition, only the static load is considered for the load generated by the buoyancy force when the empty fuel tank is completely submerged. For non-CSR bulk carriers, the typical calculation conditions are shown in Table 1.2.1. For CSR bulk carriers, the typical calculation conditions are shown in Table 1.2.2. For ore carriers, the typical calculation conditions are shown in Table 1.2.3.

(4) If there are more severe loading conditions in the loading manual, cargo hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

2.2.2 Structural model and boundary conditions

2.2.2.1 By taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the longitudinal scope of the model is at least to cover the structure of the target tank in the middle, the vertical is at least to contain the hatch coaming, and the transverse is to cover the full width. Specific scopes are to meet the applicable rules for different ship types, taking into account the influence of boundary effects. In order to facilitate applying fuel tank loads, the fuel tank model and its supporting structure are to be correctly simulated. The modeling requirements of FE model (including the structure members to be modeled, finite element types and mesh sizes , etc.) are given in Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

2.2.2.2 Corrosion deduction in the hull structure model is to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 1 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for

Classification of Sea-Going Steel Ships;

(3) For ore carriers, see Section 1 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

2.2.2.3 The boundary conditions of the model are to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(3) For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

2.2.3 Hull girder load adjustment

2.2.3.1 For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

2.2.3.2 For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

2.2.4 Strength assessment of hull structures

2.2.4.1 The yield and buckling strength of the primary hull members supporting the fuel tanks and the anti-flotation arrangement (if any) are to be assessed.

2.2.4.2 Yield assessment criteria

(1) For CSR bulk carriers, see Sections 2 and 3 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) For ore carriers, see Sections 2 and 3 of Chapter 7 of CCS Rules for Structures of Ore Carriers. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

2.2.4.3 Buckling strength assessment methods and criteria

(1) For CSR bulk carriers, see Section 4 of Chapter 8 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) For ore carriers, see Section 4 of Chapter 9 of CCS Rules for Structures of Ore Carriers. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

2.3 Oil tankers and chemical tankers

2.3.1 Load conditions

2.3.1.1 Design loads for direct calculation include local loads such as longitudinal bending moment of hull girder, internal liquid pressure of tanks and fuel tanks (including static and dynamic liquid pressure and vapor pressure of fuel tank) and external sea pressure together with the inertial forces due to ship's motion and the self-weight of hull and fuel tanks.The buoyancy load resulting from full flooding of empty fuel tanks is to be taken into account.

2.3.1.2 Taking the main hull tank in way of the center of gravity of the type C independent fuel tank as the target tank, hull girder loads include:

(1) vertical static bending moment, to be taken as the maximum permissible still water bending moment of the targeted tank;

(2) vertical wave bending moment, to be taken as the maximum value of the targeted tank. For non-CSR ships, Section 5 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships is to be complied with. For CSR oil tankers, Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships is to be complied with.

(3) Adjustment of vertical bending moment and shear force. For CSR tankers, Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships is to be complied with.

2.3.1.3 The weight of hull and independent tank is to be considered in calculation and the effect may be taken into account by setting the material density of element and acceleration field (including acceleration of gravity).

2.3.1.4 Internal dynamic pressure of the fuel tank is to be calculated according to 4.28.1.2 of PART THREE, Chapter 4 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For different sea-going conditions, combined calculation is to be carried out by multiplying a factor specified below with the acceleration component given in 4.28.2 of Chapter 4 of PART THREE. The values of acceleration(a_x, a_y, a_z) used in the calculation are shown in the attached tables 1.3.1, 1.3.2 ,1.3.3 and 1.3.4 for collision condition and static heeling condition. Acceleration factors (k_x, k_y, k_z) under various different sea-going conditions are calculated as follows:

(1) For CSR oil tankers, the acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. See Section 3 of Chapter 8 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships for details. The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations ($a_{x\text{-}env}$, $a_{y\text{-}env}$, $a_{z\text{-}env}$) at the center of gravity of the tank. The acceleration factor in each direction is to be taken as 1.0 if it exceeds 1.0;

(2) For non-CSR tankers, only vertical acceleration factor k_z is considered in sea-going conditions, and the value of acceleration factor is shown in Table 1.3.1 and Table 1.3.2.

2.3.1.5 For non-CSR ships, the liquid cargo pressure in a cargo tank is to be calculated in accordance with 1.5.5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships. The external sea pressure is to be calculated in accordance with 1.5.3 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.1.6 For CSR oil tankers, unless otherwise specified in this Section, design loads are shown in Chapter 4 of PART 9-1of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.1.7 Typical loading modes are to be considered in calculation of conditions. For a non-CSR ship with a longitudinal bulkhead, the typical calculation conditions are shown in Table 1.3.1. For a non-CSR ship with two longitudinal bulkheads, the typical calculation conditions are shown in Table 1.3.2. If there are more severe loading conditions in the loading manual, these loading conditions are also to be calculated and assessed.

2.3.2 Structural model and boundary conditions

2.3.2.1 For non-CSR ships, the main hull tank in way the center of gravity of the Type C independent fuel tank is to be taken as the target tank. If the target tank is a cargo tank in the middle, the longitudinal extent of model is to cover the target cargo tank in the middle and extend one half the length of the adjacent tanks fore and aft. If the target tank is an aft cargo tank, longitudinal range of the model is to cover the aft cargo tank, half of the engine room and half of the forebody of the aft cargo tank. If the target tank is a fore cargo tank, longitudinal range of the model is to cover the fore cargo tank, half of the aftbody of the fore cargo tank and fore peak tank. The fore peak tank finite element model may terminate at the second web frames before the collision bulkhead.The requirements for the elements and meshes used in the tank finite element method are given in 1.5.6 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.2.2 For CSR oil tankers, the cargo tank corresponding to the center of gravity of type C independent fuel tank is taken as the target tank, and the structural modeling requirements are set out in Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.2.3 The hull structure is to be included in the model. In order to facilitate the application of fuel tank load, an independent fuel tank model is to be added in the tank model. The connection of the fuel tank to the hull structure needs to be simulated using contact elements or equivalent methods.

2.3.2.4 For non-CSR ships, the boundary conditions are given in 4.2 of Appendix 1 of Chapter 5 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships..

2.3.2.5 For CSR oil tankers, the boundary conditions are given in 2.5 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships

2.3.3 Strength assessment of hull structures

2.3.3.1 The yield and buckling strength of the primary hull members supporting the fuel tanks and the anti-flotation arrangement (if any) are to be assessed.

2.3.3.2 For non-CSR ships, the stress to be assessed is the stress in local load condition combined with the stress in global load condition according to 1.5.1.9(2) of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships. The permissible stresses of primary structural members are shown in Table 5.1.2 of Appendix 1 of Chapter 5 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.3.3 For CSR oil tankers, the yield analysis criteria, i.e. permissible stresses of primary structural members, are given in Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.The criteria for collision condition, static heeling condition and flooding and anti-flotation condition(if any) are consistent with the criteria for S+D load combination.

2.3.3.4 For non-CSR ships, the buckling strength is to be checked in accordance with the requirements of 1.5.9 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships. The standard thickness deduction of members is given in Table 6.1.1of Appendix 1of Chapter 5 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships. The minimum buckling safety factor is to be taken in accordance with Table 6.1.2 of Appendix 1 of Chapter 5 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.3.5 For CSR oil tankers, the buckling strength is to be checked in accordance with the requirements of Section 4 of Chapter 8 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.3.6 For CSR oil tankers, the local structural strength analysis is to be carried out in accordance with the requirements of Section 3 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

2.4 Container Ships

2.4.1 General Requirements

2.4.1.1 These requirements are applicable to the strength assessment of the hull structure, the fuel tank and its supporting structure in the fuel tank area of an LNG-powered container ship where the fuel tank is arranged within 0.4L amidships. Where the fuel tank is arranged outside the range of 0.4L amidships, it may be assessed by reference to the applicable parts or the direct calculation requirements in CCS Rules for Structures of Container Ships (container ships in unrestricted service) and CCS Rules for Classification of Sea-Going Steel Ships (container ships in restricted service).

2.4.2 Load conditions

2.4.2.1 Design loads for direct calculation include loads such as static and dynamic hull girder loads, container cargo loads, tank internal loads (including static and dynamic liquid pressure and vapor pressure of tank), and external sea pressure.

2.4.2.2 Taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the loads of hull girder include still water load and wave load, which are to be taken as follows:

(1) still water load includes still water bending moment and still water shear force, while still water bending moment (sagging $M_{sw\text{-}sag}$ and hogging $M_{sw\text{-}hog}$) and still water shear force (Q_{sw}) are to be taken as the

maximum permissible value of the targeted tank.

(2) For container ships in unrestricted service, the hull girder wave load includes vertical wave bending moment, vertical wave shear force, horizontal wave bending moment and wave torque. According to Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships, the target value of hull girder wave load is to be determined according to the dynamic load combination factors (LCF) corresponding to different equivalent design waves.

(3) For container ships in restricted service, the hull girder wave load includes vertical wave bending moment, which is to be calculated according to 1.5.6.1(2) of Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

2.4.2.3 The weight of hull and independent tank is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model. The dynamic load of hull and independent tank structure is not included.

2.4.2.4 External pressure, including static pressure of sea water and wave pressure, is to be calculated as follows:

(1) For container ships in unrestricted service, external pressure is to be calculated in accordance with Sections 2 and 3 of Chapter 4 of CCS Rules for Structures of Container Ships;

(2) For container ships in restricted service, external pressure is to be calculated in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.2.5 Internal pressure is to be calculated separately for each load condition. Internal pressure includes static pressure of cargo, ballast water, fuel oil and LNG fuel, pressure relief valve set pressure, and dynamic pressure of cargo, ballast water, fuel oil and LNG fuel due to acceleration. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

(1) For container ships in unrestricted service, except for the fuel tank load, internal pressure of other tanks (if any) is to be calculated according to Section 6 Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, except for the fuel tank load, only the dynamic pressure due to vertical acceleration is considered, and the vertical acceleration is given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.2.6 Internal dynamic pressure of the fuel tank is to be calculated according to 4.28.1.2 of Chapter 4 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For different sea-going conditions, combined calculation is to be carried out by multiplying a certain factor with the acceleration component given in 4.28.2 of Chapter 4 of PART THREE. Acceleration factors (k_x, k_y, k_z) under various different sea-going conditions are calculated as follows:

(1) The acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships. See 3.2 of Section 3 of Chapter 4 of CCS Rules for Structures of Container Ships for details.

(2) The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations ($a_{x\text{-}env}$, $a_{y\text{-}env}$, $a_{z\text{-}env}$) at the center of gravity of the tank.

(3) For container ships in restricted service, only vertical acceleration factor k_z is considered in sea-going conditions, and the value of acceleration factor is shown in Table 1.4.2.

2.4.2.7 Container loads include still water load and dynamic load due to acceleration. Container loads are to be calculated according to each load condition. Container loads inside cargo holds are transferred to the hull structure according to the requirements of container corner load decomposition, and container loads on the hatch cover are applied to the hatch coaming stopper.

(1) For container ships in unrestricted service, the weight of the container is to be taken in accordance with Section 8 of Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the weight of the container is to be taken in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.2.8 Typical loading modes are to be considered in calculation of conditions, including the following special conditions:

(1) In the collision condition where fuel tank has the inertial force corresponding to 0.5g in the forward direction and the inertial force corresponding to 0.25g in the backward direction, only static load is considered for the external sea pressure and hull girder load in the collision condition, and only static liquid pressure is considered for the tank pressure inside the fuel tank ;

(2) In the static heeling condition, the change of external sea pressure and tank pressure due to inclination under heeling of 30°is considered, without considering the wave load;

(3) Under the flooding and anti-flotation condition, considering the buoyancy of the fuel tank due to the flooding of the area where the fuel tank is located, only the static load is considered.

2.4.2.9 Design loading conditions

(1) For container ships in unrestricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.1.

(2) For container ships in restricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.2.

(3) If there are loading conditions in the Loading Manual which are more severe than those in Table 1.4.1 and Table 1.4.2, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

2.4.3 Structural model and boundary conditions

2.4.3.1 By taking the main hull tank in way of the center of gravity of the type C independent fuel tank as the target tank, the vertical scope of the model is at least to contain the hatch coaming, and the transverse scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure may be considered. In order to facilitate applying fuel tank loads, the fuel tank model and its supporting structure are to be correctly simulated.

(1) For container ships in unrestricted service, the longitudinal scope and modeling requirements of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the longitudinal scope and modeling requirements of the model are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.3.2 Corrosion addition of the model

(1) For container ships in unrestricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the net scantling method, the corrosion addition deducted was 0.5*tc*, and the corrosion addition deducted for all buckling capacity assessment was *tc*.Corrosion addition is given in Table 1.3.2 of Section 2 of Chapter 3 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the gross scantling method, without deducting the corrosion addition. The standard thickness deduction is to be deducted for buckling capacity assessment, which is given in Table 2.6.3.4 of Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.3.3 Boundary conditions of the model

(1) For container ships in unrestricted service, the boundary conditions of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the boundary conditions of the model are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.4.3.4 The connection of the fuel tank to the hull structure needs to be simulated using contact elements or equivalent methods.

2.4.4 Hull girder load adjustment

2.4.4.1 For container ships in unrestricted service, the method and process for hull girder load adjustment are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

2.4.5 Strength assessment of hull structures

2.4.5.1 The yield and buckling strength of all primary members of the target tank (including bulkhead) are to be assessed, including:

(1) all longitudinal structural members of hull girder ;

(2) primary supporting members and bulkhead in the middle cargo tank;

(3) all structural members constituting the transverse bulkhead;

(4) primary hull members supporting the fuel tank and the anti-flotation arrangement (if any).

2.4.5.2 Yield assessment criteria

(1) For container ships in unrestricted service, yield assessment criteria are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, yield assessment criteria are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in sea-going condition.

2.4.5.3 Buckling strength assessment methods and criteria

(1) For container ships in unrestricted service, buckling strength is to be assessed according to Section 4 of Chapter 9 of CCS Rules for Structures of Container Ships..

(2) For container ships in restricted service, buckling strength is to be assessed according to Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in sea-going condition.

2.4.5.4 Fine mesh analysis of local structures

(1) For container ships in unrestricted service, the process, methods and criteria for fine mesh analysis are given in Section 3 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the process, methods and criteria for fine mesh analysis are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in sea-going condition.

2.5 Vehicle carriers and ro-ro ships

2.5.1 Load conditions

2.5.1.1 Design loads for direct calculation include local loads such as vehicle loads, fuel tank internal pressure (including static and dynamic liquid pressure and vapor pressure of fuel tank), external sea pressure together with the self-weight of the hull and fuel tank.

2.5.1.2 The weight of hull and fuel tank structure is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model.

2.5.1.3 External pressure for different conditions is to be calculated in accordance with the requirements of 7.4 of CCS Guidelines for Hull Structure of Car Carriers. External pressure includes static pressure of sea water and wave pressure.

2.5.1.4 Internal pressure includes static pressure of ballast water and fuels. For the fuel tank, pressure relief valve set pressure and dynamic pressure due to acceleration are also to be considered. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 of Section 1 and 4.2.7 of Section 2 of Chapter 4 of the Rules.

2.5.1.5 Vehicle loads are to be calculated in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers. Vehicle loads include the still water load of the vehicle and the dynamic load due to acceleration. The weight of vehicle or deck design load is to be taken in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers.

2.5.1.6 The design loading conditions for strength check of the fuel tank area are shown in Table 1.5.1. If there are loading conditions in the loading manual which are more severe than those in the Table, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

2.5.2 Structural model and boundary conditions

2.5.2.1 By taking the tank where the fuel tank is located as the target tank, the longitudinal scope is to cover the target tank in the middle and the distance between the complete fore and aft web frames or between pillars, the vertical scope of the model is to cover the uppermost deck, and the transverse scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure is to be considered. In order to facilitate applying fuel tank loads, the independent fuel tank model and its supporting structure are to be correctly simulated. The modeling requirements of hold FE model (including the structure members to be modeled, finite element types and mesh sizes, etc.) are given in 7.2 of CCS Guidelines for Hull Structure of Car Carriers.

2.5.2.2 Model boundary conditions are given in 7.5.2 of CCS Guidelines for Hull Structure of Car Carriers.

2.5.3 Strength assessment of hull structures

2.5.3.1 The yield and buckling strength of the primary hull members supporting the fuel tanks and the anti-flotation arrangement (if any) are to be assessed.

2.5.3.2 The yield assessment criteria for LC1-LC6 conditions are given in 7.6 of CCS Guidelines for Hull Structure of Car Carriers. The permissible stress for LC7 under flooding and anti-flotation condition is to be taken as $235/K$ MPa, where K is the material factor .

2.5.3.3 All the structural elements for finite element analysis as required in this Annex are to be subject to buckling strength assessment in accordance with 7.7 of CCS Guidelines for Hull Structure of Car Carriers.

Section 3 TYPE A/B INDEPENDENT FUEL TANK

3.1 General Requirements

3.1.1 The design of type A/B independent fuel tank and fuel coaming system is to meet the relevant requirements of 4.2.13 and 4.2.14 of Chapter 4 of the Rules.

3.1.2 Strength assessment of type A/B independent fuel tank supporting structure (plywood + support seatings), including vertical support, anti-rolling chock, anti-pitching chock and anti-floating chock, may be carried out by referring to the relevant requirements of Section 4 of Appendix 1 of Chapter A4 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.1.3 The relevant requirements for the structural scantling of the independent prismatic fuel tank are in accordance with the applicable part of Section 3 of Appendix 1 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.1.4 Plywood is usually provided between the fuel tank supporting seatings and the hull supporting seatings to transfer load between the two seatings by means of contacting with them.The plywood is capable of taking compression but not tension. 4.2.3 of Section 4 of Appendix 1 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk may be referred to during the simulation of such structures by finite element:

3.1.5 Yield strength assessment

3.1.5.1 Yield strength of hull structure, fuel tank structure and supporting structure are to be checked. For the plate element, its equivalent stress σ_e is to be checked and calculated according to the following formula:

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

where: σ_x — stress of element in direction x, in $\mathrm{N/mm^2}$;

σ_y — stress of element in direction y, in $\mathrm{N/mm^2}$;

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

For beam or rod elements of the face plating of primary structural members, the axial stress σ_{rod}, in $\mathrm{N/mm^2}$, is to be checked.

Permissible stresses of fuel tank structure and its supporting structure in each loading condition are given in Table 3.1.5.1.

Permissible stresses of fuel tank and supporting structures，in $\mathrm{N/mm^2}$ Table 3.1.5.1

Loading conditions	Fuel tank (type A)	Fuel tank (type B)	
	Nickel steel, carbon-manganese steel, austenitic steel and aluminium alloy [σ_e]	Nickel steel, carbon-manganese[σ_e]	Austenitic steel, aluminium alloy[σ_e]
Sea-going	Min(R_m/1.7, R_e/1.1)	Min(R_m/2, R_e/1.2)	Min(R_m/2.5, R_e/1.2)
Single side loaded	0.7Min(R_m/1.7,R_e/1.1)	0.7Min(R_m/2, R_e/1.2)	0.7Min(R_m/2.5, R_e/1.2)
Static heeling	Min(R_m/1.7, R_e/1.1)	Min(R_m/2, R_e/1.2)	Min(R_m/2.5, R_e/1.2)
Collision Flooding and anti-flotation	1.1Min(R_m/1.7,R_e/1.1)	1.1Min(R_m/2, R_e/1.2)	1.1Min(R_m/2.5, R_e/1.2)

Where: R_e—— specified minimum yield stress at room temperature ($\mathrm{N/mm^2}$). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

R_m —— specified minimum tensile strength at room temperature ($\mathrm{N/mm^2}$). For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloy, the respective *Re* and *Rm* of the welds, after any applied heat treatment, are to be used. In such cases, the transverse weld tensile strength is not to be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials are not to be incorporated in cargo containment systems.

3.1.5.2 The compressive strength and shearing strength of the plywood in the fuel tank supporting structure are to be checked. Specific requirements can be found in 4.5.2 of Section 4 of Appendix 1 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.1.6 Buckling strength assessment

3.1.6.1 The panel buckling safety factor λ is not to be less than the minimum buckling safety factor in Table 3.1.6.1.

Minimum Buckling Safety Factor Table 3.1.6.1

Condition	Fuel tank and supporting structure
Sea-going	0.9
Static heeling	0.9
Collision	0.8
Flooding and anti-flotation	0.8

3.1.7 Fuel tank fine mesh analysis and fatigue assessment requirements

3.1.7.1 Critical high stress structural areas of fuel tank structure and supporting structure are to be analyzed with fine mesh finite element models.

3.1.7.2 Fine mesh analysis of fuel tank supporting structure normally includes:

(1) Vertical support and adjacent hull structure and fuel tank structure;

(2) Anti-rolling chock and adjacent hull structure and fuel tank structure;

(3) Anti-pitching chock and adjacent hull structure and fuel tank structure;

(4) Anti-floating chock and adjacent hull structure and fuel tank structure.

3.1.7.3 The fine mesh analysis selecting principle for the fuel tank supporting structure is as follows: for details of the same type (supporting structure), a detailed analysis is to be carried out by selecting the highest stressed one and the strengthening plan of this structure may be used on details (supporting structures) of the same type. Various supporting structures of the fuel tank are to be checked separately if they are of different design form or size. Specific requirements for fine mesh analysis of fuel tank can be found in the applicable part in 4.7.1 of Section 4 of Appendix 1 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.1.7.4 Fatigue crack propagation assessment and leakage analysis for type B independent tanks may be carried out by referring to Section 4 of Appendix 3 of PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.2 Bulk carriers and ore carriers

3.2.1 Load conditions

3.2.1.1 The load conditions to be calculated for type A/B independent fuel tank are the same as those for type C independent fuel tank, as shown in 2.2.1 of this Annex.

3.2.2 Structural model and boundary conditions

3.2.2.1 By taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the longitudinal scope of the model is at least to cover the structure of the target tank in the middle, the vertical is at least to contain the hatch coaming, and the transverse is to cover the full width. Specific scopes are to meet the applicable rules for different ship types, taking into account the influence of boundary effects. In order to facilitate applying fuel tank loads, the fuel tank model and its supporting structure are to be correctly simulated. The modeling requirements of FE model (including the structure members to be modeled, finite element types and mesh sizes , etc.) are given in Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

3.2.2.2 Corrosion deduction in the hull structure model is to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 1 of Chapter 7 of PART 9-1of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(3) For ore carriers, see Section 1 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

3.2.2.3 The boundary conditions of the model are to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(3) For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

3.2.3 Hull girder load adjustment

3.2.3.1 For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

3.2.3.2 For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

3.2.4 Strength assessment of hull structures

3.2.4.1 The yield and buckling strength of the primary hull members supporting the fuel tanks and the anti-flotation arrangement (if any) are to be assessed.

3.2.4.2 Yield assessment criteria

(1) For CSR bulk carriers, see Sections 2 and 3 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) For ore carriers, see Sections 2 and 3 of Chapter 7 of CCS Rules for Structures of Ore Carriers. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

3.2.4.3 Buckling strength assessment methods and criteria

(1) For CSR bulk carriers, see Section 4 of Chapter 8 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) For ore carriers, see Section 4 of Chapter 9 of CCS Rules for Structures of Ore Carriers. The criteria for collision condition, static heeling condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination.

3.3 Container Ships

3.3.1 General Requirements

3.3.1.1 These requirements are applicable to the strength assessment of the hull structure, the fuel tank and its supporting structure in the fuel tank area of an LNG-powered container ship where the fuel tank is arranged within 0.4L amidships. Where the fuel tank is arranged outside the range of 0.4L amidships, it may be assessed by reference to the applicable parts or the direct calculation requirements in CCS Rules for Structures of Container Ships (container ships in unrestricted service) and CCS Rules for Classification of Sea-Going Steel Ships (container ships in restricted service).

3.3.2 Load conditions

3.3.2.1 Design loads for direct calculation include loads such as static and dynamic hull girder loads, container cargo loads, tank internal loads (including static and dynamic liquid pressure and vapor pressure of tank), and external sea pressure.

3.3.2.2 Taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the loads of hull girder include still water load and wave load, which are to be taken as follows:

(1) still water load includes still water bending moment and still water shear force, while still water bending moment (sagging $M_{sw\text{-}sag}$ and hogging $M_{sw\text{-}hog}$) and still water shear force (Q_{sw}) are to be taken as the maximum permissible value of the targeted tank.

(2) For container ships in unrestricted service, the hull girder wave load includes vertical wave bending moment, vertical wave shear force, horizontal wave bending moment and wave torque. According to Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships, the target value of hull girder wave load is to be determined according to the dynamic load combination factors (LCF) corresponding to different

equivalent design waves.

(3) For container ships in restricted service, the hull girder wave load includes vertical wave bending moment, which is to be calculated according to 1.5.6.1(2) of Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.2.3 The weight of hull and fuel tank is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model. The dynamic load of hull and fuel tank structure is not included.

3.3.2.4 External pressure, including static pressure of sea water and wave pressure, is to be calculated as follows:

(1) For container ships in unrestricted service, external pressure is to be calculated in accordance with Sections 2 and 3 of Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, external pressure is to be calculated in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.2.5 Internal pressure is to be calculated separately for each load condition. Internal pressure includes static pressure of cargo, ballast water, fuel oil and LNG fuel, pressure relief valve set pressure, and dynamic pressure of cargo, ballast water, fuel oil and LNG fuel due to acceleration. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

(1) For container ships in unrestricted service, except for the fuel tank load, internal pressure of other tanks (if any) is to be calculated according to Section 6 Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, except for the fuel tank load, only the dynamic pressure due to vertical acceleration is considered, and the vertical acceleration is given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.2.6 Internal dynamic pressure of the fuel tank is to be calculated according to 4.28.1.2 of Chapter 4 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For different sea-going conditions, combined calculation is to be carried out by multiplying a certain factor with the acceleration component given in 4.28.2 of Chapter 4 of PART THREE. Acceleration factors (k_x, k_y, k_z) under various different sea-going conditions are calculated as follows:

(1) The acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships. See 3.2 of Section 3 of Chapter 4 of CCS Rules for Structures of Container Ships for details.

(2) The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations ($a_{x\text{-}env}$, $a_{y\text{-}env}$, $a_{z\text{-}env}$) at the center of gravity of the tank.

(3) For container ships in restricted service, only vertical acceleration factor k_z is considered in sea-going conditions, and the value of acceleration factor is shown in Table 1.4.2.

3.3.2.7 Container loads include still water load and dynamic load due to acceleration. Container loads are to be calculated according to each load condition. Container loads inside cargo holds are transferred to the hull structure according to the requirements of container corner load decomposition, and container loads on the hatch cover are applied to the hatch coaming stopper.

(1) For container ships in unrestricted service, the weight of the container is to be taken in accordance with Section 8 of Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the weight of the container is to be taken in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.2.8 Typical loading modes are to be considered in calculation of conditions, including the following special conditions:

(1) In the collision condition where fuel tank has the inertial force corresponding to $0.5g$ in the forward direction and the inertial force corresponding to $0.25g$ in the backward direction, only static load is considered for the external sea pressure and hull girder load in the collision condition, and only static liquid pressure is considered for the tank pressure inside the fuel tank.

(2) In the static heeling condition, the change of external sea pressure and tank pressure due to inclination under heeling of 30° is considered, without considering the wave load.

(3) Under the flooding and anti-flotation condition, considering the buoyancy of the fuel tank due to the flooding of the area where the fuel tank is located, only the static load is considered.

3.3.2.9 Design loading conditions

(1) For container ships in unrestricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.1.

(2) For container ships in restricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.2.

(3) If there are loading conditions in the Loading Manual which are more severe than those in Table 1.4.1 and Table 1.4.2, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

3.3.3 Structural model and boundary conditions

3.3.3.1 By taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the vertical scope of the model is at least to contain the hatch coaming, and the transverse scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure may be considered. In order to facilitate applying fuel tank loads, the independent fuel tank model and its supporting structure are to be correctly simulated.

(1) For container ships in unrestricted service, the longitudinal scope and modeling requirements of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the longitudinal scope and modeling requirements of the model are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going

Steel Ships.

3.3.3.2 Corrosion addition of the model

(1) For container ships in unrestricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the net scantling method, the corrosion addition deducted was 0.5*tc*, and the corrosion addition deducted for all buckling capacity assessment was *tc*.Corrosion addition is given in Table 1.3.2 of Section 2 of Chapter 3 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the gross scantling method, without deducting the corrosion addition. The standard thickness deduction is to be deducted for buckling capacity assessment, which is given in Table 2.6.3.4 of Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.3.3 Boundary conditions of the model

(1) For container ships in unrestricted service, the boundary conditions of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the boundary conditions of the model are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

3.3.4 Hull girder load adjustment

3.3.4.1 For container ships in unrestricted service, the method and process for hull girder load adjustment are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

3.3.5 Strength assessment of hull structures

3.3.5.1 The yield and buckling strength of all primary members of the target tank (including bulkhead) are to be assessed, including:

(1) all longitudinal structural members of hull girder ;

(2) primary hull supporting members and bulkheads;

(3) all structural members constituting the transverse bulkhead;

(4) primary hull members supporting the fuel tank and the anti-flotation arrangement (if any).

3.3.5.2 Yield assessment criteria

(1) For container ships in unrestricted service, yield assessment criteria are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, yield assessment criteria are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in the sea-going condition.

3.3.5.3 Buckling strength assessment methods and criteria

(1) For container ships in unrestricted service, buckling strength is to be assessed according to Section 4 of Chapter 9 of CCS Rules for Structures of Container Ships..

(2) For container ships in restricted service, buckling strength is to be assessed according to Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in sea-going condition.

3.3.5.4 Fine mesh analysis of local structures

(1) For container ships in unrestricted service, the process, methods and criteria for fine mesh analysis are given in Section 3 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the process, methods and criteria for fine mesh analysis are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for static heeling condition, collision condition and flooding and anti-flotation condition are consistent with the criteria for S+D load combination in sea-going condition.

3.4 Vehicle carriers and ro-ro ships

3.4.1 Load conditions

3.4.1.1 Design loads for direct calculation include local loads such as vehicle loads, fuel tank internal pressure (including static and dynamic liquid pressure and vapor pressure of fuel tank), external sea pressure together with the self-weight of the hull and fuel tank.

3.4.1.2 The weight of hull and independent tank structure is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model.

3.4.1.3 External pressure for different conditions is to be calculated in accordance with the requirements of 7.4 of CCS Guidelines for Hull Structure of Car Carriers. External pressure includes static pressure of sea water and wave pressure.

3.4.1.4 Internal pressure includes static pressure of ballast water and fuels. For the fuel tank, pressure relief valve set pressure and dynamic pressure due to acceleration are also to be considered. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

3.4.1.5 Vehicle loads are to be calculated in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers. Vehicle loads include the still water load of the vehicle and the dynamic load due to acceleration. The weight of vehicle or deck design load is to be taken in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers.

3.4.1.6 The design loading conditions for strength check of the fuel tank area are shown in Table 1.5.1. If there are loading conditions in the loading manual which are more severe than those in the Table, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

3.4.2 Structural model and boundary conditions

3.4.2.1 By taking the tank where the fuel tank is located as the target tank, the longitudinal scope is to cover the target tank in the middle and the distance between the complete fore and aft web frames or between pillars, the vertical scope of the model is to cover the uppermost deck, and the transverse scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure is to be considered. In order to facilitate applying fuel tank loads, the independent fuel tank model and its supporting structure are to be correctly simulated. The modeling requirements of hold FE model (including the structure members to be modeled, finite element types and mesh sizes , etc.) are given in 7.2 of CCS Guidelines for Hull Structure of Car Carriers.

3.4.2.2 Model boundary conditions are given in 7.5.2 of CCS Guidelines for Hull Structure of Car Carriers.

3.4.2.3 For simulation of fuel tanks and connection structures, see 3.1.1, 3.1.2 and 3.1.4 of this Annex.

3.4.3 Strength assessment of hull structures

3.4.3.1 The yield and buckling strength of all primary members of the target tank (including bulkhead) are to be assessed, including: 1) all longitudinal structural members of hull girder ; 2) all primary supporting members and bulkhead in the middle cargo tank; 3) all structural members constituting the transverse bulkhead.

3.4.3.2 The yield assessment criteria for LC1-LC6 conditions are given in 7.6 of CCS Guidelines for Hull Structure of Car Carriers. The permissible stress for LC7 under flooding and anti-flotation condition is to be taken as 235/K MPa, where K is the material factor .

3.4.3.3 All the structural elements for finite element analysis as required in this Annex are to be subject to buckling strength assessment in accordance with 7.7 of CCS Guidelines for Hull Structure of Car Carriers.

Section 4 MEMBRANE TYPE FUEL TANK

4.1 General requirements

4.1.1 The design of cargo containment system of membrane type fuel tank is to comply with relevant requirement of 4.2.16 of Chapter 4 of the Rules.

4.2 Bulk carriers and ore carriers

4.2.1 Loading conditions

4.2.1.1 The flooding and anti-floatation condition need not be considered for calculation of membrane type fuel tanks. The load conditions for calculation of membrane type fuel tanks are the same as that for type C independent fuel tanks except for flooding and anti-floatation condition. See 2.2.1 of this Annex for details.

4.2.2 Structural models and boundary conditions

4.2.2.1 By taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the longitudinal scope of the model is at least to cover the structure of the target tank in the middle, the vertical is at least to contain the hatch coaming, and the transverse is to cover the full width. Specific scopes are to meet the applicable rules for different ship types, taking into account the influence of boundary effects. In order to facilitate applying fuel tank loads, the fuel tank model and its supporting structure are to be correctly simulated. The modeling requirements of FE model (including the structure members to be modeled, finite element types and mesh sizes , etc.) are given in Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

4.2.2.2 Corrosion deduction in the hull structure model is to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 1 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

(3) For ore carriers, see Section 1 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

4.2.2.3 The boundary conditions of the model are to follow the following rules corresponding to different ship types:

(1) For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships;

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;(3) For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

4.2.3 Hull girder load adjustment

4.2.3.1 For CSR bulk carriers, see Section 2 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-Going Steel Ships.

4.2.3.2 For ore carriers, see Section 2 of Chapter 7 of CCS Rules for Structures of Ore Carriers.

4.2.4 Strength assessment of hull structures

4.2.4.1 The primary hull members supporting the fuel tanks are to be subjected to yield and buckling strength assessment.

4.2.4.2 Yield assessment criteria

(1) For CSR bulk carriers, see Sections 2 and 3 of Chapter 7 of PART 9-1 of CCS Rules for Classification of Sea-going Steel Ships. The criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

(3) For ore carriers, see Sections 2 and 3 of Chapter 7 of CCS Rules for Structures of Ore Carriers. The

criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination.

4.2.4.3 Buckling strength assessment methods and criteria

(1) For CSR bulk carriers, see Section 4 of Chapter 8 of PART 9-1 of CCS Rules for Classification of Sea-going Steel Ships. The criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination.

(2) For non-CSR bulk carriers, see Appendix 1 of Chapter 8 of PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

(3) For ore carriers, see Section 4 of Chapter 9 of CCS Rules for Structures of Ore Carriers. The criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination.

4.3 Container ships

4.3.1 General requirements

4.3.1.1 These requirements are applicable to the strength assessment of the hull structure, the fuel tank and its supporting structure in the fuel tank area of an LNG-powered container ship where the fuel tank is arranged within 0.4*L* amidships. Where the fuel tank is arranged outside the range of 0.4*L* amidships, it may be assessed by reference to the applicable parts or the direct calculation requirements in CCS Rules for Structures of Container Ships (container ships in unrestricted service) and CCS Rules for Classification of Sea-Going Steel Ships (container ships in restricted service).

4.3.2 Load conditions

4.3.2.1 Design loads for direct calculation include loads such as static and dynamic hull girder loads, container cargo loads, tank internal loads (including static and dynamic liquid pressure and vapor pressure of tank), and external sea pressure.

4.3.2.2 Taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the loads of hull girder include still water load and wave load, which are to be taken as:

(1) still water load include still water bending moment and still water shear force, while still water bending moment (sagging $M_{sw\text{-}sag}$ and hogging $M_{sw\text{-}hog}$) and still water shear force (Q_{sw}) are to be taken as the maximum permissible value of the targeted tank.

(2) For container ships in unrestricted service, the hull girder wave load includes vertical wave bending moment, vertical wave shear force, horizontal wave bending moment, horizontal wave shear force and wave torque. According to Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships, the target value of hull girder wave load is to be determined according to the dynamic load combination factors (LCF) corresponding to different equivalent design waves.

(3) For container ships in restricted service, the hull girder wave load includes vertical wave bending moment, which is to be calculated according to 1.5.6.1(2) of Section 5 of Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships;

4.3.2.3 The weight of hull and fuel tank is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model. The dynamic load of hull and fuel tank structure is not included.

4.3.2.4 External pressure, including static pressure of sea water and wave pressure, is to be calculated as follows:

(1) For container ships in unrestricted service, external pressure is to be calculated in accordance with Sections 2 and 3 of Chapter 4 of CCS Rules for Structures of Container Ships;

(2) For container ships in restricted service, external pressure is to be calculated in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.2.5 Internal pressure is to be calculated separately for each load condition. Internal pressure includes static pressure of cargo, ballast water, fuel oil and LNG fuel, pressure relief valve set pressure, and dynamic pressure of cargo, ballast water, fuel oil and LNG fuel due to acceleration. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

(1) For container ships in unrestricted service, except for the fuel tank load, internal pressure of other tanks (if any) is to be calculated according to Section 6 Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, except for the fuel tank load, only the dynamic pressure due to vertical acceleration is considered, and the vertical acceleration is given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.2.6 Internal dynamic pressure of the fuel tank is to be calculated according to 4.28.1.2 of Chapter 4 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For different sea-going conditions, combined calculation is to be carried out by multiplying a certain factor with the acceleration component given in 4.28.2 of Chapter 4 of PART THREE. Acceleration factors (k_x, k_y, k_z） under various different sea-going conditions are calculated as follows:

(1) The acceleration at the center of gravity of the fuel tank (a_x, a_y, a_z) is to be calculated according to the dynamic load combination factors (LCF) provided in Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships. See 3.2 of Section 3 of Chapter 4 of CCS Rules for Structures of Container Ships for details.

(2) The acceleration factors (k_x, k_y, k_z) under the dynamic load condition are obtained by dividing the above acceleration by the envelope accelerations ($a_{x\text{-}env}$, $a_{y\text{-}env}$, $a_{z\text{-}env}$) at the center of gravity of the tank.

(3) For container ships in restricted service, only vertical acceleration factor k_z is considered in sea-going conditions, and the value of acceleration factor is shown in Table 1.4.2.

4.3.2.7 Container loads include still water load and dynamic load due to acceleration. Container loads are to be calculated according to each load condition. Container loads inside cargo holds are transferred to the hull structure according to the requirements of container corner load decomposition, and container loads on the hatch cover are applied to the hatch coaming stopper.

(1) For container ships in unrestricted service, the weight of the container is to be taken in accordance

with Section 8 of Chapter 4 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the weight of the container is to be taken in accordance with Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.2.8 Typical loading modes are to be considered in calculation of conditions, including the following special conditions:

(1) In the collision condition where fuel tank has the inertial force corresponding to 0.5g in the forward direction and the inertial force corresponding to 0.25g in the backward direction, only static load is considered for the external sea pressure and hull girder load in the collision condition, and only static liquid pressure is considered for the tank pressure inside the fuel tank.

(2) In the static heeling condition, the change of external sea pressure and tank pressure due to inclination under heeling of 30° is considered, without considering the wave load.

4.3.2.9 Design loading conditions

(1) For container ships in unrestricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.1.

(2) For container ships in restricted service, the design loading conditions for strength check of the fuel tank area are shown in Table 1.4.2.

(3) If there are loading conditions in the Loading Manual which are more severe than those in Table 1.4.1 and Table 1.4.2, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

4.3.3 Structural models and boundary conditions

4.3.3.1 By taking the main hull tank in way of the center of gravity of the fuel tank as the target tank, the vertical scope of the model is at least to contain the hatch coaming, and the transverse scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure may be considered. In order to facilitate applying fuel tank loads, the fuel tank model and its supporting structure are to be correctly simulated.

(1) For container ships in unrestricted service, the longitudinal scope and modeling requirements of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the longitudinal scope and modeling requirements of the model are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.3.2 Corrosion addition of the model

(1) For container ships in unrestricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the net scantling method, the corrosion addition deducted was 0.5t_c, and the corrosion addition deducted for all buckling capacity assessment was t_c.Corrosion addition is given in Table 1.3.2 of Section 2 of Chapter 3 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the finite element model for hold FE analysis and local fine mesh FE analysis is to be based on the gross scantling method, without deducting the corrosion addition. The standard thickness deduction is to be deducted for buckling capacity assessment, which is given in Table 2.6.3.4 of Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.3.3 Boundary conditions of the model

(1) For container ships in unrestricted service, the boundary conditions of the model are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the boundary conditions of the model are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

4.3.4 Hull girder load adjustment

4.3.4.1 For container ships in unrestricted service, the method and process for adjustment of hull girder loads are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

4.3.5 Strength assessment of hull structures

4.3.5.1 The yield and buckling strength of all primary members of the target tank (including bulkhead) are to be assessed, including:

(1) all longitudinal structural members of hull girder;

(2) primary hull supporting members and bulkheads;

(3) all structural members constituting the transverse bulkhead;

(4) primary hull members supporting the fuel tank.

4.3.5.2 Yield assessment criteria

(1) For container ships in unrestricted service, yield assessment criteria are given in Section 2 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, yield assessment criteria are given in Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination in the sea-going condition.

4.3.5.3 Buckling strength assessment methods and criteria

(1) For container ships in unrestricted service, buckling strength is to be assessed according to Section 4 of Chapter 9 of CCS Rules for Structures of Container Ships..

(2) For container ships in restricted service, buckling strength is to be assessed according to Appendix 2 of Chapter 7 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The assessment criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination in sea-going condition.

4.3.5.4 Local structural strength analysis

(1) For container ships in unrestricted service, the process, methods and criteria for fine mesh analysis

are given in Section 3 of Chapter 7 of CCS Rules for Structures of Container Ships.

(2) For container ships in restricted service, the process, methods and criteria for fine mesh analysis are given in Appendix 2 of Chapter 7of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

(3) The criteria for collision condition and static heeling condition are consistent with the criteria for S+D load combination in sea-going condition.

4.4 Vehicle carriers and ro-ro ships

4.4.1 Load conditions

4.4.1.1 Design loads for direct calculation include local loads such as vehicle loads, fuel tank internal pressure (including static and dynamic liquid pressure and vapor pressure of fuel tank), external sea pressure together with the self-weight of the hull and fuel tank.

4.4.1.2 The weight of hull and containment structure is to be included in the static load and the effect may be taken into account by setting the material density and acceleration field in the finite element model.

4.4.1.3 External pressure for different conditions is to be calculated in accordance with the requirements of 7.4 of CCS Guidelines for Hull Structure of Car Carriers. External pressure includes static pressure of sea water and wave pressure.

4.4.1.4 Internal pressure includes static pressure of ballast water and fuels. For the fuel tank, pressure relief valve set pressure and dynamic pressure due to acceleration are also to be considered. The set pressure of the pressure relief valve and the density of LNG fuel are provided in 4.1.3 and 4.2.7 of Chapter 4 of the Rules.

4.4.1.5 Vehicle loads are to be calculated in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers. Vehicle loads include the still water load of the vehicle and the dynamic load due to acceleration. The weight of vehicle or deck design load is to be taken in accordance with 7.4 of CCS Guidelines for Hull Structure of Car Carriers.

4.4.1.6 The design loading conditions for strength check of the fuel tank area are shown in Table 1.5.1. If there are loading conditions in the loading manual which are more severe than those in the Table, hold finite element strength analysis is to be carried out for these loading conditions, and the corresponding dynamic load conditions are to be specially considered according to the loading characteristics.

4.4.2 Structural model and boundary conditions

4.4.2.1 By taking the fuel tank as the target tank, the longitudinal scope is to cover the target tank in the middle and the distance between the complete fore and aft web frames or between pillars, the vertical scope of the model is to cover the uppermost deck, and the horizontal scope is to cover the full width. If there is a superstructure above the assessed area, the influence of the superstructure on the strength of the hull structure is to be considered.The modeling requirements of hold FE model (including the structure members to be modeled, finite element types and mesh sizes , etc.) are given in 7.2 of CCS Guidelines for Hull Structure of Car Carriers.

4.4.2.2 Model boundary conditions are given in 7.5.2 of CCS Guidelines for Hull Structure of Car Carriers.

4.4.3 Strength assessment of hull structures

4.4.3.1 The yield and buckling strength of all primary members of the target tank (including bulkhead) are to be assessed, including: (1) all longitudinal structural members of hull girder; (2) all primary supporting members and bulkhead in the middle cargo tank; (3) all structural members constituting the transverse bulkhead.

4.4.3.2 For the criteria of yield assessment, see 7.6 of CCS Guidelines for Hull Structure of Car Carriers.

4.4.3.3 All the structural elements for finite element analysis as required in this Appendix are to be subject to buckling strength assessment in accordance with 7.7 of CCS Guidelines for Hull Structure of Car Carriers.

Section 5 ANALYSIS OF TEMPERATURE FIELD

5.1 General requirements

5.1.1 This Section applies to LNG fuel tanks, including type C independent fuel tanks, type A or type B independent fuel tanks and membrane type fuel tanks.

5.1.2 Analysis of temperature field is to adopt calculation tools acceptable to CCS.

5.2 Type C independent fuel tank

5.2.1 Temperature field analysis for type C independent fuel tank is to comply with relevant requirements of Section 6 of Appendix 2 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

5.2.2 For type C independent fuel tank located on the exposed deck, the temperature field analysis of the fuel tank's saddle structure and deck may only consider thermal conduction, while convection and radiation can be omitted. The calculated temperature of the joint between the bottom of the seatings and the deck is to be no lower than -10°C under IGC ambient condition. Otherwise, the temperature field analysis considering convection and radiation is to be carried out to the deck under the fuel tank seatings and adjacent compartments.

5.2.3 Calculation of thermal stress of supporting members and fittings for type C independent fuel tank is to comply with relevant requirements of 6.5 of Section 6 of Appendix 2 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

5.3 Type A or type B independent fuel tank

5.3.1 Temperature field analysis for type A or type B independent fuel tank is to comply with relevant requirements of Section 5 of Appendix 1 of PART TWO of CCS Rules for Construction and Equipment of

Ships Carrying Liquefied Gases in Bulk.

5.3.2 Calculation of temperature field for low-cycle fatigue analysis and calculation of thermal stress of supporting members and fittings for type A or type B independent fuel tank is to comply with relevant requirements of 5.4 and 5.5 of Section 5 of Appendix 1 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

5.4 Membrane type fuel tank

5.4.1 Temperature field analysis for membrane type fuel tank is to comply with relevant requirements of Appendix 3 of Chapter 20 of PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

Appendix 1 LOADING CONDITIONS

1.1 General requirements

1.1.1 These attached tables are designed to list the typical loading conditions for direct calculation of fuel tank area of LNG sea-going ships based on the fuel tank type and ship type.

1.1.2 If there are loading conditions in the Loading Manual which are more severe than those typical loading conditions, these conditions are also subject to structural strength direct calculation.

1.2 Bulk carriers and ore carriers

1.2.1 For non-CSR bulk carriers, see Table 1.2.1 for loading conditions. LC1 to LC10 are sea-going conditions, among which LC1 to LC4 are full homogeneous sea-going conditions, LC5 to LC6 alternate loading conditions (if applicable), LC7 to LC8 ballast conditions and LC9 to LC10 multiport loading (if applicable). LC11 to LC12 are collision conditions where only static load is to be taken into account for external sea pressure and hull girder load. Only static pressure of liquid is to be considered for tank pressure within the fuel tank. The inertial force corresponding to 0.5*g* in the forward direction of fuel tank under LC 11 and the inertial force corresponding to 0.25*g* in the backward direction of fuel tank under LC 12 are to be considered. LC13 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered. LC14 is flooding and anti-floatation condition where the load caused by the buoyancy when the empty fuel tank is completely submerged is to be considered and only static load is to be taken into account.

Loading conditions for LNG fuel tanks of non-CSR bulk carriers Table 1.2.1

Types of conditions	Conditions	Fuel tank	Aft cargo tank	Ballast tank	Fuel oil tank	Draught	Still water bending moment	Wave bending moment	Accele

									ration factors (k_x, k_y, k_z)
Full homogeneous conditions	1	Full	Heavy cargo full M_{FULL}	Empty	Full	Draught= d	$\overline{M}_s$	M_w	(0,0,1)
	2	Empty	Heavy cargo full M_{FULL}	Empty	Empty	Draught= d	$\overline{M}_s$	M_w	(0,0,0)
	3	Full	Light cargo full M_{FULL}	Empty	Full	Draught= d	$\overline{M}_s$	M_w	(0,0,1)
	4	Empty	Light cargo full M_{FULL}	Empty	Empty	Draught= d	$\overline{M}_s$	M_w	(0,0,0)
Alternate loading conditions	5	Full	Heavy cargo full	Empty	Full	Draught= d	$\overline{M}_s$	M_w	(0,0

			M_{HD} $+0.1M_H$						,1)
	6	Empty	Heavy cargo full M_{HD} $+0.1M_H$	Empty	Empty	Draught= d	$\overline{M}_s$	M_w	(0,0,0)
Ballast conditions	7	Full	Empty	Full	Full	Draught=maximum ballast draught	$\overline{M}_s$	M_w	(0,0,1)
	8	Empty	Empty	Full	Empty	Draught=maximum ballast draught	$\overline{M}_s$	M_w	(0,0,0)
Multiport loading	9	Full	Light cargo full M_{FULL}	Empty	Empty	Draught=*0.83d*	$0.8\overline{M}_s$	M_w	(0,0,1)
Multiport loading	10	Empty	Light cargo full M_{FULL}	Empty	Empty	Draught=*0.83d*	$0.8\overline{M}_s$	M_w	(0,0,0)
Types of conditions	**Conditions**	**Fuel tank**	**Aft cargo tank**	**Ballast tank**	**Fuel oil tank**	**Draught**	**Still water bending moment**	**Wave bending moment**	**Acceleration of**

									fuel tank (a_x, a_y, a_z)
Collision condition	11	Full	Empty	Empty	Empty	Draught=d	$\overline{M}_s$ (Sagging)	—	(0.5g, 0, 0)
Collision condition	12	Full	Empty	Empty	Empty	Draught=d	$\overline{M}_s$ (Sagging)	—	(-0.25g, 0, 0)
Static heeling condition	13	Full	Empty	Empty	Empty	Draught=d	$\overline{M}_s$ (Sagging)	—	(0, 0.5g, 0)
Flooding and anti-floatation condition	14	Empty	Empty	Empty	Empty	Draught=d_{dam}	-	-	-

Notes:

M_H ——the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t;

M_{FULL} ——the cargo mass corresponding to cargo with virtual density filled to the top of the hatch coaming, in t, i.e.:

$$M_{FULL} = V_{FULL} \cdot \max(M_H / V_{FULL}, 1.0)$$

M_{HD} ——the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft, 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;

ρ_w ——density of sea water, to be taken as 1.025 t/m^3;

d_{dam}——z coordinate of the top of the independent fuel tank, in m;

d——scantling draught, in m;

$\overline{M}_s$ ——permissible still water bending moment, in kN/m^2;

M_w ——wave bending moment , in kN/m^2;

The acceleration under static heeling condition is gravitational acceleration component instead of inertia force imposed additionally.

1.2.2 For loading conditions of CSR bulk carriers, see Table 1.2.2 . LC1 to LC10 are sea-going conditions, among which LC1 to LC4 are full homogeneous sea-going conditions, LC5 to LC6 alternate loading conditions (if applicable), LC7 to LC8 ballast conditions and LC9 to LC10 multiport loading (if applicable). LC11 to LC12 are collision conditions where only static load is to be taken into account for external sea pressure and hull girder load. Only static pressure of liquid is to be considered for tank pressure within the fuel tank. The inertial force corresponding to 0.5g in the forward direction of fuel tank under LC11 and the inertial force corresponding to 0.25g in the backward direction of fuel tank under LC12 are to be considered. LC13 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered. LC14 is flooding and anti-floatation condition where the load caused by the buoyancy when the empty fuel tank is completely submerged is to be considered and only static load is to be taken into account.

Loading conditions for LNG fuel tanks of CSR bulk carriers Table 1.2.2

<table>
<tr><th>Condition</th><th>Description</th><th>Fuel tank</th><th>Aft cargo tank</th><th>Ballast tank</th><th>Fuel oil tank</th><th>Draught</th><th>Permissible still water bending moment%</th><th>Permissible still water shear force %</th><th>Dynamic load</th></tr>
<tr><td rowspan="7">1</td><td rowspan="7">Full homogeneous conditions</td><td rowspan="7">Full</td><td rowspan="7">Heavy cargo full M_{FULL}</td><td rowspan="7">Empty</td><td rowspan="7">Full</td><td rowspan="7">Tsc</td><td rowspan="7">100% (Sagging)</td><td rowspan="7">100%</td><td>FSM-1</td></tr>
<tr><td>BSP-1P</td></tr>
<tr><td>BSP-1S</td></tr>
<tr><td>OST-1P</td></tr>
<tr><td>OST-1S</td></tr>
<tr><td>OSA-1P</td></tr>
<tr><td>OSA-1S</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Full homogeneous conditions</td><td rowspan="3">Empty</td><td rowspan="3">Heavy cargo full</td><td rowspan="3">Empty</td><td rowspan="3">Empty</td><td rowspan="3">Tsc</td><td rowspan="3">100% (Sagging)</td><td rowspan="3">100%</td><td>FSM-1</td></tr>
<tr><td>BSP-1P</td></tr>
<tr><td>BSP-1S</td></tr>
</table>

			M_{FULL}						OST-1P OST-1S OSA-1P OSA-1S
3	Full homogeneous conditions	Full	Light cargo full M_{FULL}	Empty	Full	*Tsc*	100% (Sagging)	100%	FSM-1 BSP-1P BSP-1S OST-1P OST-1S OSA-1P OSA-1S
4	Full homogeneous conditions	Empty	Light cargo full M_{FULL}	Empty	Empty	*Tsc*	100% (Sagging)	100%	FSM-1 BSP-1P BSP-1S OST-1P OST-1S OSA-1P OSA-1S
5	Alternate loading conditions	Full	Heavy cargo full M_{HD} $+0.1M_H$	Empty	Full	*Tsc*	100% (Sagging)	100%	FSM-1 BSP-1P BSP-1S OST-1P OST-1S OSA-1P OSA-1S
6	Alternate loading conditions	Empty	Heavy cargo full M_{HD} $+0.1M_H$	Empty	Empty	*Tsc*	100% (Sagging)	100%	FSM-1 BSP-1P BSP-1S OST-1P OST-1S OSA-1P OSA-1S
7	Ballast conditions	Full	Empty	Full	Full	Draught= maximum ballast draught	100% (Hogging)	100%	HSM-2 FSM-1 BSP-1P BSP-1S BSR-1P BSR-1S OST-1P OST-1S OST-2P OST-2S OSA-1P OSA-1S
8	Ballast conditions	Empty	Empty	Full	Empty	Draught= maximum ballast draught	100% (Hogging)	100%	HSM-2 FSM-1 BSP-1P BSP-1S BSR-1P BSR-1S OST-1P OST-1S OST-2P

									OST-2S
									OSA-1P
									OSA-1S
9	Multiport loading	Full	Light cargo full M_{FULL}	Empty	Empty	*0.83Tsc*	80% (Hogging)	100%	FSM-1
									OSA-1P
									OSA-1S
							80% (Sagging)	100%	FSM-1
									BSP-1P
									BSP-1S
									OST-1P
									OST-1S
10	Multiport loading	Empty	Light cargo full M_{FULL}	Empty	Empty	*0.83Tsc*	80% (Hogging)	100%	FSM-1
									OSA-1P
									OSA-1S
							80% (Sagging)	100%	FSM-1
									BSP-1P
									BSP-1S
									OST-1P
									OST-1S
Condition	**Description**	**Fuel tank**	**Aft cargo tank**	**Ballast tank**	**Fuel oil tank**	**Draught**	**Permissible still water bending moment%**	**Permissible still water shear force%**	**Acceleration of fuel tank**
11	Collision conditions	Full	Empty	Empty	Empty	T_{SC}	100% (Sagging)	100%	(0.5*g*,0,0)
12	Collision conditions	Full	Empty	Empty	Empty	T_{SC}	100% (Sagging)	100%	(-0.25*g*,0,0)
13	Heeling conditions	Full	Empty	Empty	Empty	T_{SC}	100% (Sagging)	100%	(0,0.5*g*,0)
14	flooding and anti-floatation condition	Empty	Empty	Empty	Empty	T_{dam}	-	-	-

Notes:

T_{sc}——strcutural draught, in m;

M_H——the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t;

M_{FULL}——the cargo mass corresponding to cargo with virtual density filled to the top of the hatch coaming, in t, i.e.,

$$M_{FULL}=V_{FULL}\cdot\max(M_H/V_{FULL},1.0)$$

M_{HD}——the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft, in t;

M_{BW}——maximum ballast water mass in cargo holds, 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;

ρ_w——density of sea water, to be taken as 1.025 t/m^3;

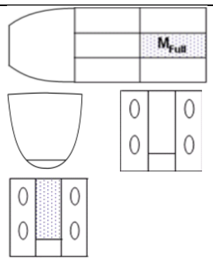
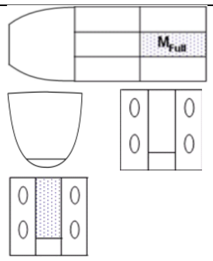
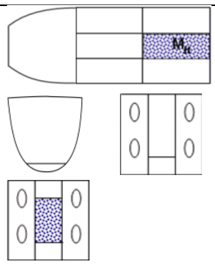
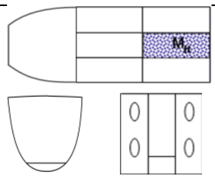
d_{dam}——z coordinate of the top of the independent fuel tank, in m;

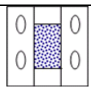
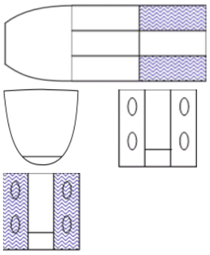
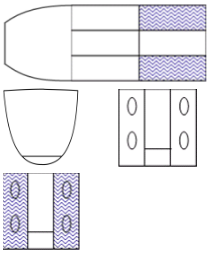
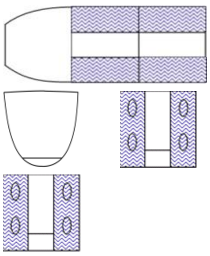
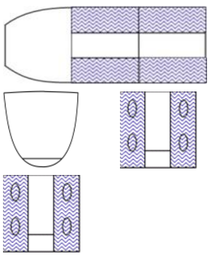
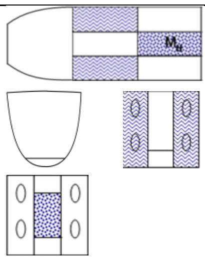
For dynamic load conditions, see Section 2 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-going Steel Ships;

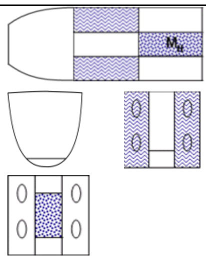
The acceleration under static heeling condition is gravitational acceleration component instead of inertia force imposed additionally.

1.2.3 For loading conditions of ore carriers, see Table 1.2.3. LC1 to LC10 are sea-going conditions, among which LC1 to LC4 are full homogeneous sea-going conditions, LC5 to LC6 ballast conditions, LC7 to LC8 maximum ballast conditions (if applicable) and LC9 to LC10 multiport loading. LC11 to LC12 are collision conditions where only static load is to be taken into account for external sea pressure and hull girder load. Only static pressure of liquid is to be considered for tank pressure within the fuel tank. The inertial force corresponding to $0.5g$ in the forward direction of fuel tank under LC11 and the inertial force corresponding to $0.25g$ in the backward direction of fuel tank under LC12 are to be considered. LC13 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered. LC14 is flooding and anti-floatation condition where the load caused by the buoyancy when the empty fuel tank is completely submerged is to be considered and only static load is to be taken into account.

Loading conditions for LNG fuel tanks of ore carriers **Table 1.2.3**

Conditions	Description	Loading patterns	Fuel tank	Draught	Permissible still water shear force%	Permissible still water bending moment%	Dynamic load conditions
1	Full homogeneous conditions-Light cargo		Full	T_{SC}	100%	80% SAG	FVM-1 BSP-1P OST-1P OSA-1P
2	Full homogeneous conditions-Light cargo		Empty	T_{SC}	100%	80% SAG	FVM-1 BSP-1P OST-1P OSA-1P
3	Full homogeneous conditions-Heavy cargo		Full	T_{SC}	100%	80% SAG	FVM-1 BSP-1P OST-1P
4	Full homogeneous conditions-Heavy cargo		Empty	T_{SC}	100%	80% SAG	FVM-1 BSP-1P OST-1P

							
5	Normal ballast conditions		Full	$T_{BAL\text{-}N}$	100%	100% HOG	HVM-2
							FVM-1
							BSP-1P
							OST-1P
							OSA-1P
					100%	100% SAG	FVM-1
							BSR-1P
							OST-1P
6	Normal ballast conditions		Empty	$T_{BAL\text{-}N}$	100%	100% HOG	HVM-2
							FVM-1
							BSP-1P
							OST-1P
							OSA-1P
					100%	100% SAG	FVM-1
							BSR-1P
							OST-1P
7	Maximum ballast conditions		Full	$T_{BAL\text{-}H}$	100%	100% HOG	HVM-2
							FVM-1
							BSP-1P
							OST-1P
							OSA-1P
					100%	100% SAG	HVM-1
							BSR-1P
							BSP-1P
8	Maximum ballast conditions		Empty	$T_{BAL\text{-}H}$	100%	100% HOG	HVM-2
							FVM-1
							BSP-1P
							OST-1P
							OSA-1P
					100%	100% SAG	HVM-1
							BSR-1P
							BSP-1P
9	Multiport loading		Full	0.67 T_{SC}	100%	50% SAG	FVM-1
							OST-1P
					100%	50% HOG	FVM-1
							BSR-1P
							OSA-1P
10	Multiport loading		Empty	0.75 T_{SC}	100%	50% SAG	FVM-1
							OST-1P

					100%	50% HOG	FVM-1 BSR-1P OSA-1P
Conditions	**Description**	**Loading patterns**	**Fuel tank**	**Draught**	**Permissible still water shear force%**	**Permissible still water bending moment%**	**Acceleration of fuel tank**
11	Collision conditions	Fuel tank full, other tanks empty	Full	T_{SC}	100%	100% SAG	(0.5*g*,0,0)
12	Collision conditions	Fuel tank full, other tanks empty	Full	T_{SC}	100%	100% SAG	(-0.25*g*,0,0)
13	Heeling conditions	Fuel tank full, other tanks empty	Full	T_{SC}	100%	100% SAG	(0,0.5*g*,0)
14	Flooding and anti-floatation condition	Fuel tank empty, fuel tank flooded	Empty	T_{dam}	-	-	-

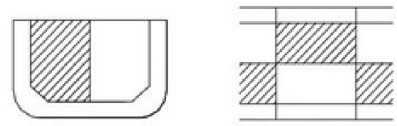
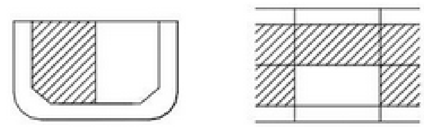
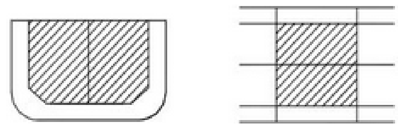
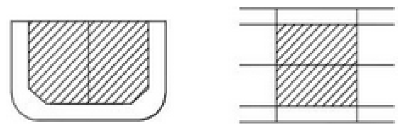
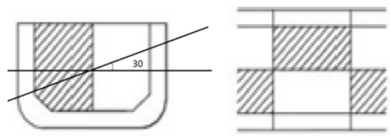
Notes:
(1) For 100% still water shear force , judgement for correction is to be made;
(2) In the table, T_{SC}—Scantling draught, in m; $T_{BAL\text{-}N}$—Normal ballast draught, in m; $T_{BAL\text{-}H}$—Maximum ballast draught, in m; HOG—Hogging, HAG—Sagging, — Heavy cargo, — Light cargo, —Ballast water;
(3) M_H: Cargo mass in a cargo hold at maximum draught in the loading manual; M_{FULL}: Cargo mass in a cargo hold when homogeneously fully loaded to the top of the hatch coaming, to be taken as Max（M_H /V_{FULL},1.0）V_{FULL}, but not less than M_H; V_{FULL}: Volume of cargo hold;
(4) The acceleration under static heeling condition is gravitational acceleration component instead of inertia force imposed additionally;
(5) T_{dam}——z coordinate of the top of the independent fuel tank, in m;
(6) For dynamic load conditions, see Section 2 of Chapter 4 of CCS Rules for Structures of Ore Carriers.

1.3 Oil tankers and chemical tankers

1.3.1 For loading conditions of non-CSR carriers with one longitudinal bulkhead, see Table 1.3.1 . LC1 to LC3 are sea-going conditions, where external sea pressure is to be taken into account. LC4 to LC5 are collision conditions where only static load is to be taken into account for external sea pressure. Only static pressure of liquid is to be considered for cargo oil tank pressure. The inertial force corresponding to 0.5*g* in the forward direction of fuel tank under LC4 and the inertial force corresponding to 0.25*g* in the backward direction of fuel tank under LC5 are to be considered. LC6 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered.

Loading conditions for LNG fuel tanks of non-CSR tankers with one longitudinal bulkhead
Table 1.3.1

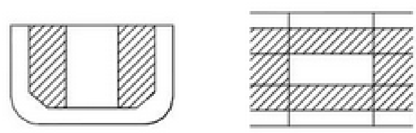
Conditions	Draught	Acceleration factors (k_x, k_y, k_z)	Still water bending moment	Wave bending moment	Loading patterns
LC1	d	(0,0,1)	$\bar{M}_S$	M_w	

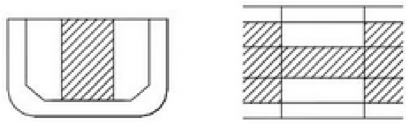
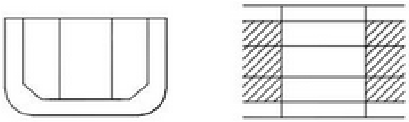
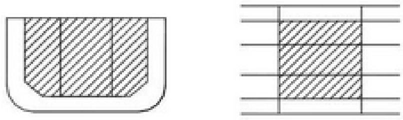
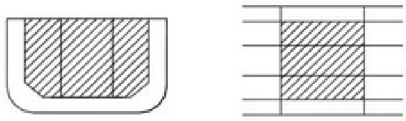
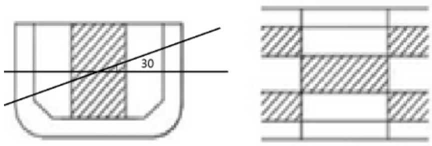
LC2	d	(0,0,1)	$\bar{M}_S$	M_w	
LC3	d	(0,0,1)	$\bar{M}_S$	M_w	
Conditions	**Draught**	**Acceleration (a_x, a_y, a_z)**	**Still water bending moment**	**Wave bending moment**	**Loading patterns**
LC4	d	(0.5g,0,0)	$\bar{M}_S$	-	
LC5	d	(-0.25g,0,0)	$\bar{M}_S$	-	
LC6	d	(0,0.5g,0)	$\bar{M}_S$	-	

Notes:
(1) The acceleration under static heeling condition LC6 is gravitational acceleration component instead of inertia force imposed additionally;
(2) d-Scantling draught; $\bar{M}_s$ -Permissible still water bending moment; M_w-Wave bending moment.

1.3.2 For loading conditions of non-CSR carriers with two longitudinal bulkheads, see Table 1.3.2. LC1 to LC3 are sea-going conditions, where external sea pressure is to be taken into account. LC4 to LC5 are collision conditions where only static load is to be taken into account for external sea pressure. Only static pressure of liquid is to be considered for cargo oil tank pressure. The inertial force corresponding to 0.5g in the forward direction of fuel tank under LC4 and the inertial force corresponding to 0.25g in the backward direction of fuel tank under LC5 are to be considered. LC6 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered.

Loading conditions for LNG fuel tanks of non-CSR tankers with two longitudinal bulkheads
Table 1.3.2

Conditions	**Draught**	**Acceleration factors (k_x, k_y, k_z)**	**Still water bending moment**	**Wave bending moment**	**Loading patterns**
LC1	d	(0,0,1)	$\bar{M}_S$	M_w	

LC2	d	(0,0,1)	$\bar{M}_S$	M_w	
LC3	d	(0,0,1)	$\bar{M}_S$	M_w	
Conditions	**Draught**	**Acceleration (a_x, a_y, a_z)**	**Still water bending moment**	**Wave bending moment**	**Loading patterns**
LC4	d	(0.5g,0,0)	$\bar{M}_S$	-	
LC5	d	(-0.25g,0,0)	$\bar{M}_S$	-	
LC6	d	(0,0.5g,0)	$\bar{M}_S$	-	

Notes:

(1) The acceleration under static heeling condition LC6 is gravitational acceleration component instead of inertia force imposed additionally;

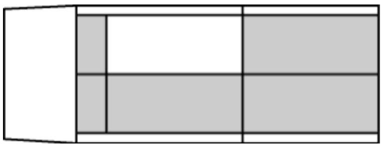
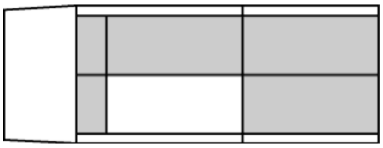
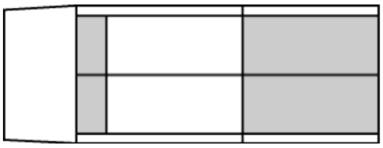
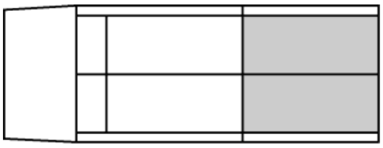
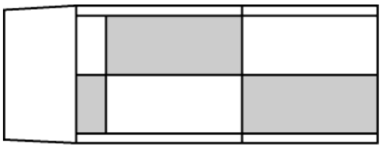
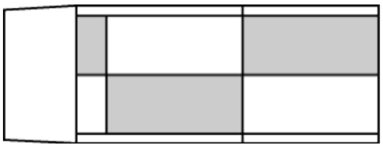
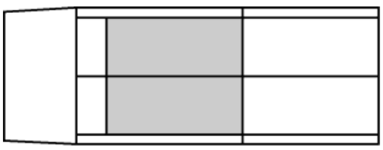
(2) d-Scantling draught; $\bar{M}_s$ -Permissible still water bending moment; M_w-Wave bending moment.

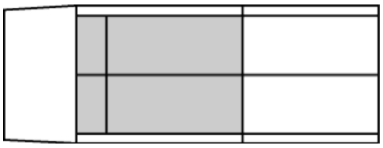
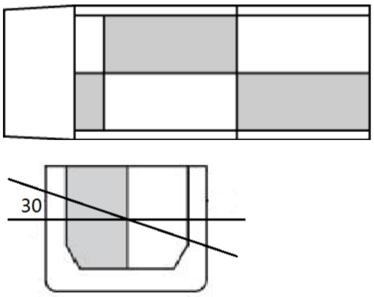
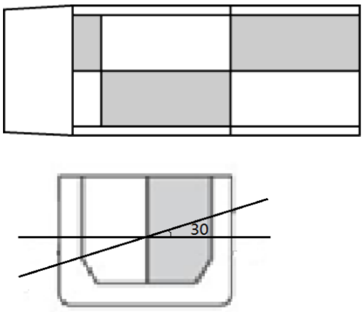
1.3.3 For design load combinations of CSR tankers with one longitudinal bulkhead, see Table 1.3.3. B1 to B5 are sea-going conditions, where static component and dynamic component of loads are to be imposed at the same time. B8 is collision condition where only static load is to be taken into account for external sea pressure. Only static pressure of liquid is to be considered for cargo oil tank pressure. The inertial force corresponding to 0.5g in the forward direction of B8a fuel tank and the inertial force corresponding to 0.25g in the backward direction of B8b fuel tank are to be considered. B9 to B10 are static heeling conditions where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered.

Loading conditions for LNG fuel tanks of CSR oil tankers with one longitudinal bulkhead

Table 1.3.3

Conditions	Loading patterns	Still water loads	Dynamic load conditions

		Draught	**Permissible still water bending moment%**	**Permissible still water shear force%**	
B1		$0.9T_{SC}$	100% (Sagging)	100%	HSM-1
					BSP-1P
			100% (Hogging)	100%	HSM-2
B2		$0.9T_{SC}$	100% (Sagging)	100%	HSM-1
			100% (Hogging)	100%	HSM-2
					BSP-1S
B3-1		$0.9T_{SC}$	100% (Sagging)	100%	BSP-1P/S
			100% (Hogging)	100%	BSP-1P/S
B3-2		$0.9T_{SC}$	100% (Sagging)	100%	BSP-1P/S
			100% (Hogging)	100%	BSP-1P/S
B4		$0.6T_{SC}$	100% (Hogging)	75%	BSP-1P
					OSA-1P/S
B5		$0.6T_{SC}$	100% (Hogging)	75%	BSP-1S
					OSA-1P/S
Conditions	**Loading patterns**	**Draught**	**Permissible still water bending moment%**	**Permissible still water shear force%**	**Acceleration of fuel tank**
B8a		$0.33T_{SC}$	100% (Hogging)	100%	(0.5g,0,0)

B8b		$0.33T_{SC}$	100% (Sagging)	100%	$(-0.25g,0,0)$
B9		$0.6T_{SC}$	100% (Sagging)	100%	$(0,0.5g,0)$
B10		$0.6T_{SC}$	100% (Sagging)	100%	$(0,0.5g,0)$

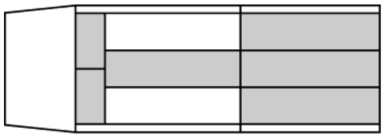
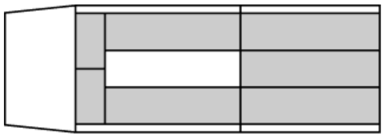
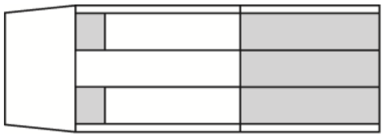
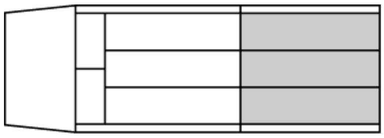
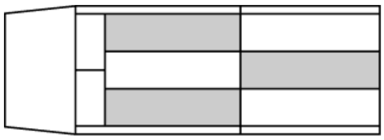
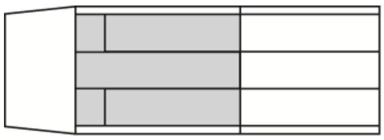
Notes:
(1) The acceleration under static heeling conditions B9 and B10 is gravitational acceleration component instead of inertia force imposed additionally;
(2) T_{SC}- Scantling draught;
(3) For dynamic load conditions, see Section 2 of Chapter 4 of PART 9-1 of CCS Rules for Classification of Sea-going Steel Ships.

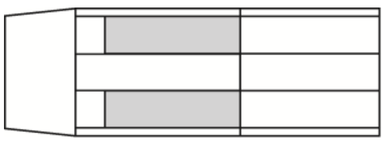
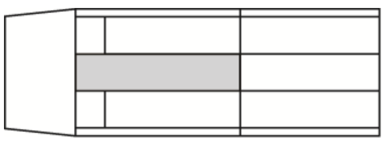
1.3.4 For design load combinations of CSR tankers with two longitudinal bulkheads, see Table 1.3.4. A1 to A5 are sea-going conditions, where static component and dynamic component of loads are to be imposed at the same time. A9 to A10 are collision condition where only still water load is to be taken into account for external sea pressure. Only static pressure of liquid is to be considered for cargo oil tank pressure. The inertial force corresponding to $0.5g$ in the forward direction of A9 fuel tank and the inertial force corresponding to $0.25g$ in the backward direction of A10 fuel tank are to be considered. A12a to A12b are static heeling conditions where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and wave load is not to be considered.

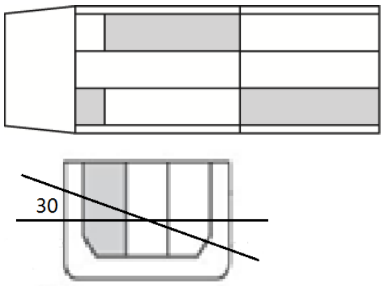
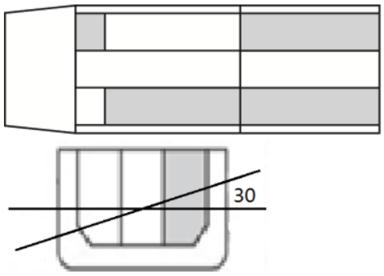
Loading conditions for LNG fuel tanks of CSR oil tankers with two longitudinal bulkheads

Table 1.3.4

Conditions	**Loading patterns**	**Still water loads**			**Dynamic load conditions**
		Draught	**Permissible still water bending moment%**	**Permissible still water shear force%**	
A1		$0.9T_{SC}$	100% (Sagging)	100%	HSM-1

			100% (Hogging)	100%	HSM-2
A2		$0.9T_{SC}$	100% (Sagging)	100%	HSM-1
					BSR-1P
					BSR-1S
			100% (Hogging)	100%	HSM-2
					OSA-1P/S
A3-1		$0.65T_{SC}$	100% (Sagging)	100%	BSP-1P/S
			100% (Hogging)		HSM-2
A3-2		$0.65T_{SC}$	100% (Sagging)	100%	BSP-1P/S
			100% (Hogging)		BSP-1P/S
A4		$0.6T_{SC}$	100% (Sagging)	100%	BSP-1P/S
					HSM-1
A5-2		$0.65T_{SC}$	100% (Hogging)	100%	HSM-2

Conditions	**Loading patterns**	**Draught**	**Permissible still water bending moment%**	**Permissible still water shear force%**	**Acceleration of fuel tank**
A9		$0.25T_{SC}$	100% (Hogging)	100%	(0.5g,0,0)
A10		$0.25T_{SC}$	100% (Hogging)	100%	(-0.25g,0,0)

A12a		*0.33*T_{SC}	N/A	N/A	(0,0.5g,0)
A12b		*0.33*T_{SC}	N/A	N/A	(0,0.5g,0)
Note: The acceleration under static heeling conditions A12a and A12b is gravitational acceleration component instead of inertia force imposed additionally.					

1.4 Container ships

Loading conditions for LNG fuel tanks of container ships in unrestricted service   Table 1.4.1

Conditions	Description	Weight of containers	Fuel tank	Ballast tank	Draught	Still water bending moment	Still water shear force	Dynamic load conditions
LC1	Empty cargo hold, fuel oil tank and ballast tank full loaded	-	Full load	Full load	T_{BAL}	Taken from the loading manual	Q_{sw}	HVM-2 HVS-2 FVM-2 BSR-2P BSP-2P OST-2P OHM-2S OHS-2P OVA-1S
LC2-1	Homogeneous loading of 40 ft heavy containers	40 ft heavy containers	Empty	Empty	T_{SC}	$M_{sw\text{-}Sag}$	Q_{sw}	HVM-1 HVS-1 FVM-1 BSR-1P BSP-1P OST-1P OHM-1S OHS-1P OVA-2S
LC2-2			Full load					
LC3	Homogeneous loading of 40 ft light containers	40 ft light containers	Full load	Empty	T_{SC}	$M_{sw\text{-}Hog}$	Q_{sw}	HVM-2 HVS-2 FVM-2 BSR-2P BSP-2P OST-2P OHM-2S OHS-2P OVA-1S
LC4-1	Homogeneous loading of 20 ft heavy containers	20 ft heavy containers. If there is combination loading on deck, the maximum combination is to be taken on deck and maximum design stack weight of 20 ft is to be taken for compartment.	Empty	Empty	$0.9T_{SC}$	$M_{sw\text{-}Hog}$	Q_{sw}	HVM-2 HVS-2 FVM-2 BSR-2P BSP-2P OST-2P OHM-2S OHS-2P OVA-1S
LC4-2			Full load					
LC5-1	One 40 ft bay within hold and on the hatch cover near the fuel tank is empty; the rest within hold and on the hatch cover is fully loaded	40 ft heavy containers	Empty	Empty	T_{SC}	$M_{sw\text{-}Hog}$	Q_{sw}	HVM-2 HVS-2 FVM-2 BSR-2P BSP-2P OST-2P OHM-2S OHS-2P OVA-1S
LC5-2			Full load			$M_{sw\text{-}Sag}$		HVM-1 HVS-1 FVM-1 BSR-1P BSP-1P OST-1P OHM-1S

								OHS-1P OVA-2S
Conditions	**Description**	**Weight of containers**	**Fuel tank**	**Ballast tank**	**Draught**	**Still water bending moment**	**Still water shear force**	**Acceleration of fuel tank**
LC6	Inertial loads corresponding to 0.5g in the forward direction	-	Full load	Empty	T_{BAL}	Taken from the loading manual	Q_{sw}	(0.5g,0,0)
LC7	Inertial loads corresponding to 0.25g in the backward direction	-	Full load	Empty	T_{BAL}	Taken from the loading manual	Q_{sw}	(-0.25g,0,0)
LC8	30° static heeling conditions	-	Full load	Empty	T_{BAL}	Taken from the loading manual	Q_{sw}	(0,0.5g,0)
LC9	flooding and anti-floatation condition	-	Empty	Empty	T_{dam}	-	-	-

Notes:

(1) The acceleration under static heeling condition LC8 is gravitational acceleration component instead of inertia force imposed additionally;

(2) T_{SC}——scantling draught, in m;

T_{BAL}——ballast draught, in m;

Heavy containers——the weight of a container is to be taken as permissible stack weight divided by the maximum number of tiers;

Light containers——the weight of a container is not to be greater than the values taken as follows:

Within hold: 55% of the weight of heavy containers;

On hatch cover: to be taken as 90% of the permissible stack weight divided by the maximum number of tiers or 17 tons, whichever is the lesser;

(3) If the fore and aft structure of the LNG fuel tank is asymmetrical, the empty 40 ft bay forward and aft the LNG fuel tank is to be checked respectively for LC5 condition;

(4) LC6 and LC7 are collision conditions where dynamic load is to be considered for the fuel tank and only static load is to be considered for the rest. The inertial force corresponding to 0.5g in the forward direction of LC6 fuel tank and the inertial force corresponding to 0.25g in the backward direction of LC7 fuel tank are to be considered. LC8 is static heeling condition where only the change of external sea pressure and tank pressure caused by a 30° heeling of hull is to be taken into account and dynamic load is not to be considered. Membrane type LNG fuel tank is in no need of considering LC9 condition.

(5) T_{dam}——z coordinate of the top of the independent fuel tank, in m;

(6) For dynamic load conditions, see Section 2 of Chapter 4 of CCS Rules for Structures of Container Ships.

Loading conditions for LNG fuel tanks of container ships in restricted service Table 1.4.2

Conditions	**Description**	**Weight of containers**	**Fuel tank**	**Ballast tank**	**Draught**	**Still water bending moment**	**Wave bending moment**	**Acceleration of fuel tank**
LC1-1	Homogeneous loading of 40 ft light containers	40 ft light containers	Empty	Taken from the loading manual	T_{sc}	Hogging	Hogging	(0,0,-1.0)
LC1-2			Full					
LC1-3			Alternate loading					
LC2-1	Homogeneous loading of 40 ft heavy containers	40 ft heavy containers	Empty	Taken from the loading manual	0.9T_{sc}	Sagging	Sagging	(0,0,-1.0)
LC2-2			Full					
LC2-3			Alternate loading					
LC3-1			Empty			Hogging	Hogging	(0,0,-1.0)

LC3-2	One 40 ft bay within hold and on the hatch cover near the fuel tank is empty; the rest within hold and on the hatch cover is fully loaded	40 ft heavy containers	Full	Taken from the loading manual	T_{sc}			
LC3-3			Alternate loading					
LC6	Inertial loads corresponding to 0.5g in the forward direction	-	Full load	Empty	T_{BAL}	Taken from the loading manual	-	(0.5g,0,0)
LC7	Inertial loads corresponding to 0.25g in the backward direction	-	Full load	Empty	T_{BAL}	Taken from the loading manual	-	(-0.25g,0,0)
LC8	30° static heeling conditions	-	Full load	Empty	T_{BAL}	Taken from the loading manual	-	(0,0.5g,0)
LC9	flooding and anti-floatation condition	-	Empty	Empty	T_{dam}	-	-	-

Notes: (1) The acceleration under static heeling condition LC8 is gravitational acceleration component instead of inertia force imposed additionally;
(2) Membrane type LNG ships are in no need of considering LC9 condition.

1.5 Car carriers and ro-ro ships

1.5.1 For loading conditions of fuel tank strength assessment for car carriers and ro-ro ships, see Table 1.5.1.

Loading conditions for LNG fuel tanks of ro-ro ships Table 1.5.1

Conditions	Description	Vehicle	fuel tank	Ballast tank	Draught	Dynamic load conditions
LC1	Full load conditions	Deck design load	Full load	Empty	T_{SC}	Vertical accelerated speed
LC2	Ballast conditions	-	Empty	Full load	T_{BAL}	Wave dynamic pressure
LC3	Rolling conditions	Deck design load	Full load	Empty	T_{SC}	Angle of roll
LC4	Inertial loads corresponding to 0.5g in the forward direction	Deck design load	Full load	Empty	T_{SC}	(0.5g,0,0)
LC5	Inertial loads corresponding to 0.25g in the backward direction	Deck design load	Full load	Empty	T_{SC}	(-0.25g,0,0)
LC6	30° Static heeling conditions	Deck design load	Full load	Empty	T_{SC}	(0,0.5g,0)
LC7	Flooding and anti-floatation condition	Deck design load	Empty	Empty	Fuel tank top	-

Notes: (1) T_{SC}—— scantling draught, in m;

(2) T_{BAL}——ballast draught, in m;

(3) LC7 is only applicable to independent fuel tank located within the hold and the check area covers anti-floatation arrangement and its supports.

ANNEX 4 TANK STRUCTURE STRENGTH ASSESSMENT OF INLAND WATERWAYS SHIPS

Section 1 TYPE C INDEPENDENT TANKS

1.1 Loading conditions

1.1.1 Type C independent tanks, including directly attached supporting structures①, are to be subjected to a finite element strength assessment in the loading conditions listed in Table 1.1.1 (1); the hull structures in fuel tank area, including attached supporting structures, are to be subjected to a finite element strength assessment in the loading conditions listed in Table 1.1.1 (2) . In addition, direct strength calculation is to be carried out in the loading conditions, if any, more severe than those listed in Table 1.1.1 (1) and Table 1.1.1 (2).

Loading Conditions of Type C Independent Tanks

(Including directly attached supporting structures)

Table 1.1.1 (1)

No.	Loading conditions	Description
1	Ultimate design condition: seagoing conditions	Acceleration loads[1] caused by tank weight, fuel weight, minimum tank temperature[2], vapour pressure and ship motions
2	Ultimate design condition: static heeling conditions	At the heel angle of 0°/10°/20°, with tank weight, fuel weight, and at minimum tank temperature[2] and vapour pressure
3	Ultimate design condition: rolling conditions	At the maximum rolling angle of 0°/5°/10°, with tank weight, fuel weight, and at minimum tank temperature[2], fuel fluid dynamic pressure and vapour pressure
4	Accident design condition: collision conditions	（1）With tank weight, fuel weight, at minimum tank temperature[2] and vapour pressure, with collision loads[3] (a, 0, 0); （2）With tank weight, fuel weight, at minimum tank temperature[2] and vapour pressure, with collision loads[3] (-a/2, 0, 0);
5	Test conditions[4]	At test loads[4], with tank weight and fuel weight
Notes: 1. Acceleration loads due to ship's motions are calculated according to 4.2.7.4 (1) ④of the Rules, including structural inertial loads and fuel fluid dynamic pressure; 2. See the relevant requirements for temperature field analysis specified in 1.3.3 of this Annex; 3.The inertial force from collision loads is calculated according to 4.2.7.5 (1) of the Rules, including structural inertial loads		

① E.g., Supporting structures are directly connected to the tank shell as associated structure of the tank.

No.	Loading conditions	Description
and fuel fluid dynamic pressure; 4. Test loads and stress criteria are to comply with the relevant requirements of 13.5.4 of the Rules. Test conditions may also be checked with a recognized standard, e.g., GB/T 150 Pressure vessels.		

Loading Conditions of Hull Structures in Tank Area

(Including directly attached supporting structures)

Table 1.1.1 （2）

No.	Loading conditions	Description
1	Ultimate design condition: seagoing conditions	Acceleration[1] loads caused by structure weight and ship motions
2	Ultimate design condition: static heeling conditions	At the heel angle of 0°/10°/20° and with structure weight
3	Ultimate design condition: rolling conditions	At the maximum rolling angle of 0°/5°/10°/ship movement and with structure weight
4	Accident design condition: flooding conditions	Loads[2] due to structure weight and flooding on ship, in case of the tank located below the freeboard deck
Notes: 1. Acceleration loads due to ship's motions are calculated according to 4.2.7.4 (1) ④of the Rules； 2. Loads due to flooding on ship are calculated according to 4.2.7.5 (2) of the Rules.		

1.1.2Where hull structures within the fuel tank area, within the range of finite element modelling, are subject to the water pressure overboard, consideration is also to be given to the effects of the water pressure overboard. The water pressure overboard is to comply with 1.9.7.6 of Chapter 1, PART ONE of CCS Rules for the Construction of Inland Waterways Steel Ships.

1.2 Strength assessment of hull structures in tank areas, including directly attached supporting structures

1.2.1For hull structures in tank area and directly attached supporting structures, a three-dimensional FE model is to be applied in the strength calculation, and the modelling is to comply with 1.9.4, Section 9, Chapter 1, PART ONE of CCS Rules for the Construction of Inland Waterways Steel Ships.

1.2.2The model extent, boundary conditions and strength criteria are to comply with 1.9.7, Section 9, Chapter 1, PART ONE of CCS Rules for the Construction of Inland Waterways Steel Ships.

1.2.3Where the tank is located within 0.4L amidships, the resultant stress from longitudinal bending stress and local bending stress of the longitudinal hull support structures in tank area under seagoing conditions is also to be checked (see Table 1.1.1 (2) of this Annex). The resultant stress may be obtained by combining the local stress calculated under seagoing conditions with the longitudinal bending stress calculated according to CCS Rules for the Construction of Inland Waterways Steel Ships. A hull girder method or FE method may be applied in the longitudinal bending stress calculation of longitudinal supporting structures.

1.3 Strength assessment of type C independent tanks (including directly attached supporting structures)

1.3.1 Unless specified otherwise in the Rules, the direct strength calculation of type C independent tanks and directly attached supporting structures (including laminated wood) are to comply with Section 4, Annex 2, PART TWO of CCS Rules for Construction and Equipment of Inland Waterways Ships Carrying Liquefied Gases in Bulk, as appropriate.

1.3.2 The following is to apply for the boundary conditions of FE model:

1.3.2.1 Where the tank is not directly connected to the supporting structure, the connection of tank to laminated wood and laminated wood to laminated wood is to be surface-to-surface connection, and the connection of laminated wood to supporting structure is to be of rigidity restriction.

1.3.2.2 Where the tank is directly connected to the supporting structure, the boundary condition for connection of the hull to supporting structure is to be set as: all connections, except for axial movements (along the tank length) at the loose end of supporting structure, are of rigidity restriction.

1.3.3 Type C independent tanks of a unconventional design (e.g., bilobe tanks and trilobal tanks) or the area where type C independent tanks are located specially required for temperature distribution and thermal stress analysis (applying 4.2.15.2 (5) (c) of the Rules), are to refer to the requirements for temperature field analysis and corresponding thermal stress analysis of Section 6, Appendix 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

1.3.4 The tank stress criteria is to comply with 4.2.15.3 to 4.2.15.5 of the Rules, while fatigue analysis not required. For supporting structures directly connected to the tank, the stress criteria is to comply with 1.9.7.7 of PART ONE of CCS Rules for the Construction of Inland Waterways Steel Ships, and the seating and its tripping brackets are to comply with the strength criteria for floor plate or bottom girder in line with them.

1.3.5 For the stress criteria for laminated wood, Table 5.6.2 (2), Section 5, Appendix 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk may be referred to.

Section 2 OTHER TANKS

2.1 **General requirements**

2.1.1Where inland waterways ships are fitted with a tank other than type C independent tank, the finite element strength assessment of tank and tank area is to be subject to special consideration by CCS.

ANNEX 5 ELECTRONIC CONTROL SYSTEMS

Section 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 Electronic control systems in this Annex include electronic control systems of gas engine, gas control systems and gas safety systems.

1.1.2 Power supply of electronic control systems is to comply with the relevant requirements of 11.1.3.12 of Chapter 11 of the Rules.

Section 2 TECHNICAL REQUIREMENTS FOR ELECTRONIC CONTROL SYSTEMS OF GAS ENGINES

2.1 General requirements

2.1.1 The design, manufacture and inspection of the electronic equipment used for electronic control systems of gas fuel engine, including software design, are to comply with the relevant requirements in PART SEVEN of CCS Rules for Classification Sea-going Steel Ships, PART FOUR of CCS Rules for the Construction of Inland Waterways Steel Ships and CCS Guidelines for Type Approval Test of Electrical and Electronic Products.

2.2 Functional requirements

2.2.1 Electronic control system of gas fuel engine means a system where a electronic control is applied to systems of gas fuel injection, fuel oil injection (if any), etc. It controls parameters such as amount of gas fuel, proportion with air, time of ignition, amount of oil fuel (if any), etc. With the function of optimization the operation of the engine data exchange to other system. The electronic system is composed of sensors, electronic control units (ECU), actuators, panel for local control and interfaces for remote control.

2.2.2 Monitoring and control function of electronic control system of gas engine are to comply with the relevant requirements in Chapter 7 and Chapter 12 of the Rules.

2.2.3 Visual and audible alarms are to be given at local and remote control place in the event of failure of the main source of electrical power.

2.2.4 Electronic control systems are to have the functions of failure self-diagnosis and fail-safe protection. In case of failure, the system is to immediately perform a self-diagnose and initiate appropriate fail-safe protection to maintain operation of the gas fuel engine.

2.2.5 Local controls and data communication interfaces for remote control system in central control room or bridge control system are to be provided.

2.2.6 The monitoring performed by the electronic control system is to be able to initiate alarms when main functions of sensors, ECUs and actuators fail, and visual and audible alarms are to be given at local and remote control place.

2.2.7 An electronic control system is to have a capacity for detection of combustion status of an engine, including but not limited to detonation, misfiring, combustion pressure in the cylinder, as applicable, etc., and an alarm is to be given in case of any fault or abnormality mentioned above, except documentation demonstrating that no risk above occurs in the engine.

2.2.8 On detection of detonation or misfiring, its severity is to be determined and the engine is to be adjusted according to its safety control plan, to ensure its operation. Measures may be adopted, including but not limited to the follows:

(1) change ignition advance angle preferentially to ensure continuous running of the engine in the event of mild detonation;

(2) decrease the engine load and give an alarm in the event of moderate detonation;

(3) stop the engine and indicate the failure in the event of powerful detonation;

(4) change ignition energy to ensure continuous running of the engine in the event of misfiring.

2.2.9 An electronic control system is to have a capacity for air-fuel ratio closed loop control or similar one to ensure the engine running in a reasonable range. The electronic control system is to be capable of adjusting automatically the gas and air flow and activating an alarm in case of abnormality. The alarm is to include but not limited to too high and too low air-fuel ratio.

2.2.10 Ignition, oil injection and gas injection modules of the electronic control system are to have a capacity for self-inspection and fault diagnosis. These modules are to be capable of indicating the conditions of high tension ignition coils and oil and gas injection solenoid valves in real time and activating an alarm for short or open circuit.

2.2.11 Electronic control systems are to be provided with test ports to facilitate monitoring and maintenance.

2.2.12 Electronic control systems are to be able to transfer signals such as states and alarms of the engine to vessel monitoring system, which including, but not limited to the items in Table 2.2.12.

Output Items **Table 2.2.12**

Categories	Indication	Remarks
Status	Running	
	Stop	
	Running only on oil	
	Running only on gas	
	Running on dual fuel	Only applicable to dual fuel engines
	Normal running	
	Local controlling	

	Remote controlling	
Alarms	Synthesize alarms/failure of electronic	Detailed failure information is needed.
	Synthesize alarms/failure of engine	Detailed failure information is needed.
Shutdown status	Normal shutdown	
	Emergency shutdown	
	Fault shutdown	

2.3 Design requirements

2.3.1 Those devices in the electronic control system which will affect normal operation of the main propulsion engine in case of functional failure, such as ECUs and crankshaft rotation angle indicators, are to be provided as dual systems. The type and function of such dual systems are to be fully identical. When one system fails, the other will automatically take over so as to maintain normal operation of the engine and an alarm will be given at the same time. For dual fuel engines, it may be accepted in design that the ECU will be replaced by the spare mechanical governor or an ECU in oil operation mode in case of failure of ECU in the gas operation mode of a dual fuel engine, to maintain continuous running of the engine.

2.3.2 Where the provision in 2.3.1 of this Annex is impracticable, the gas engine is not to be suitable for a ship only fitted with one this type of engine which is the only power source. This is to be indicated in the products certificate.

2.3.3 Where an ECU consists of more control modules and communicates via a foreign bus, it is suggested to provide a redundant bus to ensure that a failure of single communication line will not result in loss of control.

2.3.4 The space between the ignition coil and the high voltage wire is to be so designed to ensure that no high voltage leakage occurs.

2.3.5 The components and parts of an ECU are to be capable of replacement considering their functions and scantlings, and be capable of quick disassembly, replacement and installation considering the structure.

2.3.6 For corrosive materials, anticorrosive coating is to be provided. Where parts made of different metals contact directly with each other, means are generally to be provided to prevent electrolytic corrosion.

2.3.7 The installation of components of an electronic control system is to comply with the requirements for their installation positions on the engine, interface dimension, joints, screening, heat and shock resistance. The components are to be capable of being easily installed and fixed on the gas engine. The wiring of all electronic circuits is to be secure and reliable to prevent loosening during operation.

2.3.8 Where installing components with vibration dampers, sufficient spacing is to be left around to avoid collision with adjacent components or structures.

2.4 Testing requirements

2.4.1 Type testing

(1) In addition to the relevant requirements of CCS Guidelines for Type Approval Test of Electric and Electronic Products, type testing of electronic control systems is to comply with the requirements of this Annex.

(2) Normal function of electronic control system, such as control and monitoring function, is to be confirmed in type testing. These functional tests are to be carried out with the gas fuel engine, including all type tests required in Appendix 1, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

(3) The effective functions and failure processing of an electronic control system are to be verified during type testing, including, but not limited to the following items:

① confirmation of software version;

② availability of back-up sensor in case of a failure of one crankshaft position sensor①;

③ availability of back-up control module in case of a failure of one control module①;

④ verification of the availability of local control in case of a failure of remote control;

⑤ verification of the availability of remote control in case of a failure of local control;

⑥ working conditions and effectiveness of failure recording;

⑦ automatic switchover to another power supply in case of a failure of one of main source of electrical powers without any impact to the availability of the control system;

⑧ effectiveness of ECU parameter monitoring of test ports.

2.4.2 Factory testing combined with gas engine

(1) Factory testing of an ECU combined with gas engine is to comply with the requirements for the monitoring and control of gas engine in the Rules, and to be finished.

(2) The availability of an ECU is to be verified in testing, in general including the following items (as applicable):

① confirmation of software version;

② functions of gas injection valves;

③ functions of firing/ignition control modules;

④ functions of back-up control module in case of a failure of one control module①;

⑤ functions of back-up sensor in case of a failure of one crankshaft position sensor①;

⑥ availability of external interfaces;

⑦ other appropriate fault and functional testing.

2.4.3 Testing on board

(1) In addition to on board testing specified in Appendix 1, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships for combined with gas engine, an ECU is to be subjected to the

---

① If gas engine could change to use pure diesel oil automatically to maintain the operation in case of failure of electronic control system, the effective function of this automatic mode change process instead of the back-up unit in the event of one unit failing is to be verified.

following testing, as applicable:

① verification of data exchanging function with the navigation control system, monitoring system and gas control system of the ship;

② automatic switchover to another power supply in case of a failure of one of main source of electrical powers;

③ fault simulation to test, to the maximum extent, the functions of alarm and monitoring related to the ECU.

Section 3 GAS CONTROL SYSTEMS AND GAS SAFETY SYSTEMS

3.1 General requirements

3.1.1 The design, manufacture and inspection of the electronic equipment used for the gas control system and gas safety system, including software design, are to comply with the relevant requirements in PART SEVEN of CCS Rules for Classification Sea-going Steel Ships or PART FOUR of CCS Rules for the Construction of Inland Waterways Steel Ships and CCS Guidelines for Type Approval Test of Electrical and Electronic Products.

3.2 Functional requirements

3.2.1 Electronic control system is to be in effective and reliable operation when functioning normally.

3.2.2 All automatic and remotely operated main tank values, master gas fuel valves, double block and bleed valves, ventilation valves are to be controlled by electronic control system.

3.2.3 In addition to the monitoring, alarm and protecting functions specified in Table 12.4.2 of the Rules, a gas control system is to properly monitor the components of the gas supply system, such as fuel pumps, heaters and compressors, to ensure safe and stable supply to prevent against a surge pressure and not appropriate temperature in the gas pipes.

3.2.4 A gas safety system is to have the monitoring, alarm and protecting functions as listed in Table 12.4.3 of the Rules. Any additional function may be considered for the gas safety system where it can be demonstrated that this function is in compliance with the design principles, integrity and reliability of the gas safety system.

3.2.5 Alarms of the gas control system and gas safety system are to be located in the navigation bridge or continuously manned control room or onboard safety centre.

3.2.6 An audible and visual alarm is to be given in case of a failure of the main source of electrical power of the gas control system and gas safety system.

3.2.7 A gas safety system is to have a capacity of self-inspection, and to be capable of alarm in case of a failure of main functions of its sensors and control equipment.

3.3 Design requirements

3.3.1 The sensors are to be required for stable and normal operational performance for a long time. The measuring range and frequency characteristic (if applicable) of sensors are to be matched with the expected maximum variation range and variation of velocity of the parameters being detected. The sensors are to possess suitable accuracy and sensitivity.

3.3.2 The sensors are to be mechanically robust and durable, having good mechanical protection, reliable electrical connections and good insulated property.

3.3.3 The sensors are to be located that they can properly reflect the monitored parameters and are readily accessible for testing and renewal. Where the sensors are located in positions inaccessible for renewal, a standby sensor is to be fitted.

3.3.4 Instruments used for displaying and alarming are to be located in a position with sufficient illumination and readily observation and easy for operation and maintenance.

3.3.5 Instruments are not to be located in a position where vibration, mechanical damage, strong electromagnetic interference, high temperature or sharp change of temperature may occur.

3.3.6 There is to be room for extension of the connecting pipes and lines of pneumatic and hydraulic actuators, not impedinge the action of the actuators.

3.4 Type tests

3.4.1 The type tests of gas control systems and gas safety systems are to comply with the relevant requirements of CCS Guidelines for Type Approval Test of Electric and Electronic Products.

3.4.2 The effectiveness of the functions of gas control systems and gas safety systems are also to be verified in the type testing. If this is not impracticable, the fault signal at each monitoring point is to be simulated to verify the effectiveness of the system’s actions.

3.5 Testing on board

3.5.1 A testing program is to be prepared before the test and submitted to CCS for approval.

3.5.2 During on board testing, it is to be verified that the equipment of gas control systems and gas safety systems have been correctly installed and the whole system runs normally.

3.5.3 At least the following items are to be included in the test, as applicable:

(1) automatic switchover to another power supply in case of a failure of one of main source of electrical powers;

(2) examination of telecommunication lines and communication functions of distributed control systems and fieldbus control systems;

(3) simulation of input conditions to inspect logical output;

(4) testing the analog input and output for a analog control system (if fitted) and testing the calculation and control functions;

(5) simulation of input to examine the interlock functions of calculation, control and alarm, functional testing of operation screen and measurement of the corresponding control output.