CHINA CLASSIFICATION SOCIETY

Rules for Natural Gas Fuelled Ships

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Publisher's Note

With the rapid development of natural gas fuelled ships, China Classification Society (hereinafter referred to as CCS) amends the Rules for Natural Gas Fuelled Ships, 2013 and thus provides the Rules for Natural Gas Fuelled Ships, 2017 (hereinafter referred to as the Rules) , based on IGF Code adopted by resolution MSC.391 (95) of IMO together with years of scientific research achievements and industry development.

In the Rules, the provisions in Times New Roman are the original requirements of IGF Code, and those in Italic Type are the requirements of CCS.

The Rules after the entry into force will replace the Rules for Natural Gas Fuelled Ships, 2013.

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CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 *Rules for Natural Gas Fuelled Ships (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 requirements of the Rules, natural gas fuelled ships are to comply with the relevant requirements of CCS Rules for Classification of Sea-going Steel Ships, Rules for Construction of Sea-going Ships Engaged in Domestic Voyages or Rules for the Construction of Inland Waterways Steel Ships (hereinafter referred to as the Relevant Rules), noting the relevant requirements of the flag Administration, if any.*

1.1.1.3 *The retrofit of existing ships' diesel engine(s) to gas fuel engine(s) is to be considered as major conversion, and to comply with the relevant requirements of the flag Administration or the Rules and CCS Guidelines for the Implementation of Ships' Major Conversion. For the ships assigned a notation of DFDR(m) according to CCS Guidelines for Natural Gas Fuel Ready Ships, the retrofit of the main engine to dual fuel engine(s) may not be regarded as major conversion unless the flag Administration specifiess otherwise.*

1.1.1.4 *Unless those expressly specified in this Chapter, the relevant terms which are 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 length of ship defined in the relevant rules of CCS.

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

1.1.2.4 *A **bunkering station** is a location or space which contains gas bunkering connections, gas return connections (if any), related valves and control systems, etc.*

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

1.1.2.6 **CNG** means compressed natural gas.

[1] Such as IEC 60079 Explosive Atmospheres, IEC 60092-502 Electrical Installations in Ships—Special Features—Tankers, or GB 3836 Explosive Atmospheres.

1.1.2.7 **Control stations** are those spaces in which the ship’s radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized and engine control rooms. The spaces where the fire recording or fire control equipment is centralized are also to be considered as fire control stations.

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 A **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 an internal combustion engine that can burn oil fuel and natural gas simultaneously or operate on oil fuel or natural gas only.

1.1.2.12 ***Double walled pipe*** *means a pipe used for gas fuel supply to engines. It consists of the inner pipe and 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 requirements of the Rules.*

1.1.2.13 An **enclosed space** means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally[2].

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 A **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) A **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) An **interbarrier space** is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

[2] Refer to GB/T 22189 Electrical Installations in Ships—Special Features—Tankers or IEC 60092-502 Electrical Installations in Ships—Special Features—Tankers.

(3) A **tank connection space** means a space enclosing all tank connections and valves.

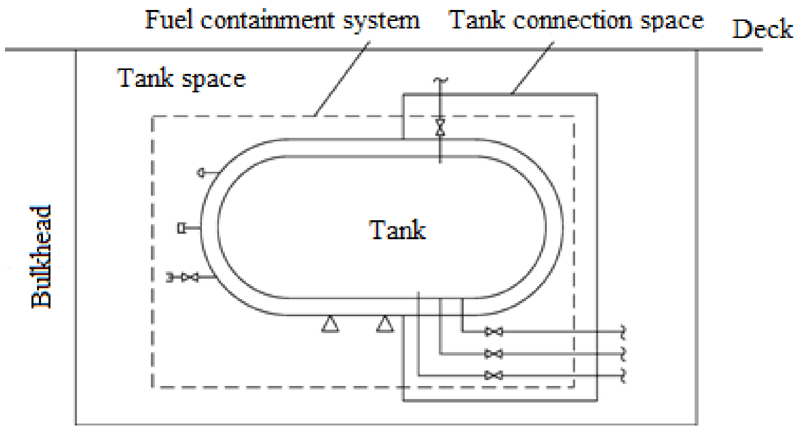


Figure 1.1.2.17 Fuel containment system within an enclosed space

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

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

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

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

1.1.2.23 A **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 A **gas valve unit space** means a gastight space or a valve box inside which valves are fitted for controlling or adjusting the gas supply to the gas engine.

1.1.2.25 An h**azardous 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 .*

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 the relevant rules of CCS.

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 gas tight layer (membrane) supported through insulation by the adjacent hull structure.

1.1.2.35 *A* ***master gas valve*** *means an automatic stop valve located outside the engine room on the gas supply line and as close to the heater (if appropriate) as possible. The main tank 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 main gas supply pipe or on each branch gas supply pipe.*

1.1.2.36 A **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 An **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 *A* ***portable tank*** *means the tank which can be moved out board for bunkering by hoisting or ro-ro operation.*

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 A **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 A **semi-enclosed space** means a space 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[3].

1.1.2.43 A **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 inside the gas fuel systems, flange connections, pump seals, compressors or pump

[3] Refer to GB/T 22189 Electrical Installations in Ships—Special Features—Tankers or IEC 60092-502 Electrical Installations in Ships—Special Features—Tankers.

sealing device etc.

1.1.2.44 *A **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.

For sea-going ships engagedin 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 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) The hazardous area is to be fitted only with equipment necessary for operational purposes,and their performance is to be compatible with the working environment and approved by CCS;

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

(7) Compartments and parts are to be suitably protected to prevent external damage;

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

(9) It is to be arranged for 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 are to be arranged;

(15) Fire detection, protection and extinction 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 the followings:

① the applicable rules, guidelines, 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 release [4] 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 spaces 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

[4] Double wall fuel pipes are not considered as potential sources of release.

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 impedeG 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 notations	*Comments*	
NaturalGasFuel	*使用天然气为燃料*	*The notation may be assigned to the ships of which the main propulsion and/or auxiliary machinery uses natural gas or natural gas and oil fuel as a fuel, except for liquefied gas carriers*

1.1.5 Alter native design

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

1.1.5.2 However CCS does not allow operational methods or procedures to be made 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 this chapter 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 assessments need 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 is to as a minimum 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 and submitted to CCS for approval.

1.1.6.4 *Risk assessments are to be conducted according to Annex 1 of the Rules.*

Section 2 PLANS AND DOCUMENTS

1.2.1 Plans and documents for approval

1.2.1.1 *In addition to those specified in CCS rules and regulations, the following plans and documents are to be submitted to CCS in triple for approval:*

(1) *Ship arrangements*

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

② *fuel containment system;*

③ *fuel preparation room, if any;*

④ *gas fuel bunkering system, including bunkering connections;*

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

⑥ *ventilation pipes, doors and openings in the fuel preparation room and other gas hazardous spaces;*

⑦ *entrances and air inlets into accommodation and service spaces and control stations;*

⑧ *air lock (if any) and its structures;*

⑨ *penetrations in bulkheads, if any;*

⑩ *instruction of drip trays or other protection means;*

⑪ *hazardous area zones classification;*

(2) *Piping systems*

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

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

③ *technical documents for branches, return pipes, elbows, expansion joints, bellows and similar 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 tubes 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; and*

⑫ *displacement calculations of tank pressure relief valves.*

(3) *Ventilation systems*

① *arrangement and instruction (e.g. displacement calculations etc.) of mechanical ventilation systems in hazardous areas, including the capacity and arrangement of fans and their motors, structures and material of the moving parts and covers of fans; and*

② *arrangement of double wall pipes (vent pipes).*

(4) Fire-fighting appliances and systems

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

② *arrangement of fire detection systems;*

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

④ *arrangement of dry powder fire-extinguishing arrangements.*

(5) *Electrical systems*

① *All electrical equipment located in hazardous areas together with the following associated information are to be included in their arrangement plan:*

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

(b) *degree of protection;*

(c) *hazardous classification of the area where the electrical equipment is installed.*

② *Verification information*[5] *of intrinsically safe circuits, including the verification of the voltage, current, inductance and capacitance.*

[5] The maximum inductance and capacitance are the total of the cable out to the hazardous area plus the values of connected equipment. The values of permissible input voltage, input current of each intrinsically safe apparatus is to be greater than or equal to the values respectively of the associated apparatus. Refer to IEC publication 60079-14: "Explosive atmosphere-Part 14: Electrical installations design, selection and erection" or equivalent standards.

③ *list of certified explosion-proof equipment.*

(6) *Control, monitoring and safety systems*

① *arrangement and instruction of gas detection and alarm systems, including probes, alarm arrangements and alarm set points;*

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

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

④ *electricity schematic diagram and monitoring list of the gas fuel bunkering and supplying system.*

(7) *Test guidelines and procedures*

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

Note: The actual drawing names may be different from those mentioned above, but the drawings are to show the requirements above.

1.2.2 Plans and documents for information

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

(1) *thermal stress analysis of piping with a design temperatures colder than minus 110°C;*

(2) *insulation arrangement of low temperature piping;*

(3) *risk analysis report, if applicable.*

1.2.3 Plans and documents on board

1.2.3.1 *In addition to those specified in CCS rules and regulations, the following documents are to be kept on board:*

(1) one gas fuel system operational booklet, which is to comply with the requirements specified in 12.4.1.2, Chapter 14 of this Rules; and

(2) one periodic test scheme for the instruments and equipment of gas control, monitoring and safety systems, which is to contain test intervals, requirements and direction and so on. For the instruments and equipment used for emergency shutoff, which are 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 other instruments and equipment.

Section 3 PRODUCTS SURVEYS

1.3.1 General requirements

1.3.1.1 *Product surveys 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 procedures, methods, types and conditions of surveys, preparations of surveys in advance, survey and test requirements and preservation of plans, documents, certificates, records and reports of the ship, are to comply with CCS Regulations for Classification of Sea-going Ships Engaged on Domestic Voyages or Regulations for Classification of Inland Waterways Ships.*

1.4.2 Surveys under construction

1.4.2.1 *In addition to the requirements for ships of CCS relevant rules and regulations, the surveys during construction are to cover the following items:*

(1) *installation and testing of gas engines, boilers (if any) and gas turbine (if any);*

(2) *installation and testing of the fuel containment system, according 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 or regulations for classification or the regulations.*

(3) *installation and testing of the fuel bunkering system;*

(4) *installation and testing of the fuel supplying system, including the heat exchanger;*

(5) *installation and testing of the ventilation system of the machinery space containing gas engine(s), fuel storage hold space, double walled pipes, tank connection space (if any) and fuel preparation room (if any);*

(6) *installation and testing of the remote closing device of the gas engine;*

(7) *check of the location and quantity of gas detectors and testing the gas detection and alarm system;*

(8) *installation and testing of the fuel bunkering system and fuel supplying system;*

(9) *confirmation and safety inspection of explosion-proof equipment or anti-igniting equipment. Where the safety of explosion-proof electrical equipment depends on the action of protection arrangement (e.g. overload protective relay) and/or alarm arrangement (e.g. no volt alarm of pressurized equipment), a function test is to be carried out for the protection arrangement and alarm arrangement to verify the accuracy of the action and alarm set values;*

(10) *confirmation of the positive pressure ventilation ability of the spaces protected by positive pressure. The clarification time at the lowest ventilation discharge is to be tested and recorded in the relevant document, and the responding valve to carry out safety measures (shutoff and/or alarm) at abnormal pressure is to be verified;*

(11) *function tests of ventilation equipment located in the space of which the hazardous class depends on mechanical ventilation; the ventilation is to be enough and the alarm for the fault of ventilation systems is to be correct;*

(12) *verification of installation of equipment and cables of intrinsically safe circuits;*

(13) *installation and test of means of fire protection and extinction;*

(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 relevant rules (if applicable), the following items are to be carried out:*

(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 *calibrating the maximum opening pressure setting of tank pressure relief valves;*

④ *inspecting whether the pressure and temperature indicators (if any) and attached alarms are in order;*

⑤ *inspecting any erosion, corrosion, scratch, indent, deformation, weld defect, frosting or condensation of the shell of vacuum insulated type C independent tanks;*

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;*

(2) *checking the heat exchanger and confirming that its operation and heating capacity comply with the technical specifications;*

(3) *Examining whether the sealing devices of tank connection spaces and gas valve unit spaces are in order;*

(4) *Examining whether the doors, side scuttles and windows of the end bulkheads of the superstructure and deckhouse facing the hazardous area 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 LNG 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) *examining whether the drip tray (if any) and its insulation to the deck are in order;*

(8) *examining whether the ventilation system and air lock (if any) of working spaces and the ventilation shutdown device of accommodation spaces are in order;*

(9) *examining whether the manually remote ESD unit is in order;*

(10) *examining the vent pipe system, including vent masts and protective screening. Special attention is to*

be given to the expansion joints and brackets on gas pipes;

(11) *examining whether the electrical installations in hazardous areas are in order, and checking the maintenance repair records;*

(12) *examining and testing the gas detection systems to confirm that they are in normal working condition;*

(13) *inspecting and confirming that no significant changes have been made to the arrangement of structural fire protection of the fuel tank, bunkering station and machinery space containing any engine(s) etc.;*

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

(15) *examining whether the water-spraying fire-extinguishing system is satisfactory;*

(16) *examining whether the dry powder fire-extinguishing system is satisfactory;*

(17) *check of gas fuel system operational manual;*

(18) *inspecting safety earthing of pipes and tanks to the hull, if applicable;*

(19) *checking the maintenance repair records of the fuel system, such as the engine logbook.*

1.4.3.2 *Intermediate surveys: In addition to the survey items in CCS relevant rules and 1.4.3.1 of the Rules, the following items are to be carried out:*

(1) *confirming that the fans used for mechanical ventilation of hazardous spaces have been provided with spare parts;*

(2) *examining visually the pressure, temperature and liquid level instruments of tanks and LNG piping by contrast; A simulation test may be accepted to the inaccessible sensors. Including alarm tests and safety functional tests.*

(3) *testing of the vacuum rate*[6] *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.*

1.4.3.3 *Special surveys: In addition to the survey items in CCS relevant rules (if applicable) and 1.4.3.2 of the Rules, the following items are to be carried out:*

(1) *Fuel containment systems*

① *The gas tanks with manholes are to be opened up to visually examine the following:*

(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 bracket of vapour pipe, liquid meter to tank body.*

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

② *A gas tightness test is to be carried out to gas tanks and their vapour and liquid pipes, and the test medium is to be dry and clean nitrogen or air. Before the test, air is not to be used as the test medium unless the gas composition in the tank is examined to be qualified;*

③ *A hydraulic test is to be carried out to gas tanks together with their vapour pipes and liquid pipes. 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 and vacuum relief valves are to be opened out for examination, and the valve settings are to be calibrated, if applicable;*

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.*

(2) *Checking of the set value of pressure relief valves on gas and liquid fuel pipes;*

(3) *Valves of gas pipes are to be calibrated, and the valves may be dismantled for setting with air or other applicable gas;*

(4) *Heat exchangers are to be opened up for examination and tested for performance;*

(5) *Examining the inert gas generator to confirm that the generated inert gas is compliance with the technical specifications and the generator is in order;*

(6) *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 are to be carried out, and the satisfactory condition of pressure relief valves confirmed;*

(7) *Removing the shaft seal on the gastight bulkhead and examining the sealing device;*

(8) *Each compressor being opened up to examine the moving parts, 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;*

(9) *examination of the pipes covered with insulation material by removing sufficient insulation material to confirm the situation of the pipe. A special inspection is to be carried out to the sealing condition; and*

(10) *For gas fuel engines, in addition to the special survey items specified for diesel engines in CCS relevant rules, the following items are to be carried out: general inspection of the ducts or cover enclosure of gas pipes, inspection of discharge or inerting equipment for pipes, and operating testing of gas fuel engines at work.*

CHAPTER 2 SHIP DESIGN AND ARRANGEMENT

Section 1 GENERAL PROVISIONS

2.1.1 Goal

2.1.1.1 The goal of this Chapter is to provide the technical requirements for safe location, 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) The fuel tanks are to be located in such a way that the probability for the tank(s) 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 led to a safe location in the open air;

(3) The access 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 are to be protected against mechanical damage;

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

(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, pressure relief systems are to be suitably designed and fitted to the exhaust system;*

(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/or bunkering station.*

Section 2 ARRANGEMENT OF TANKS

2.1.1 General requirements

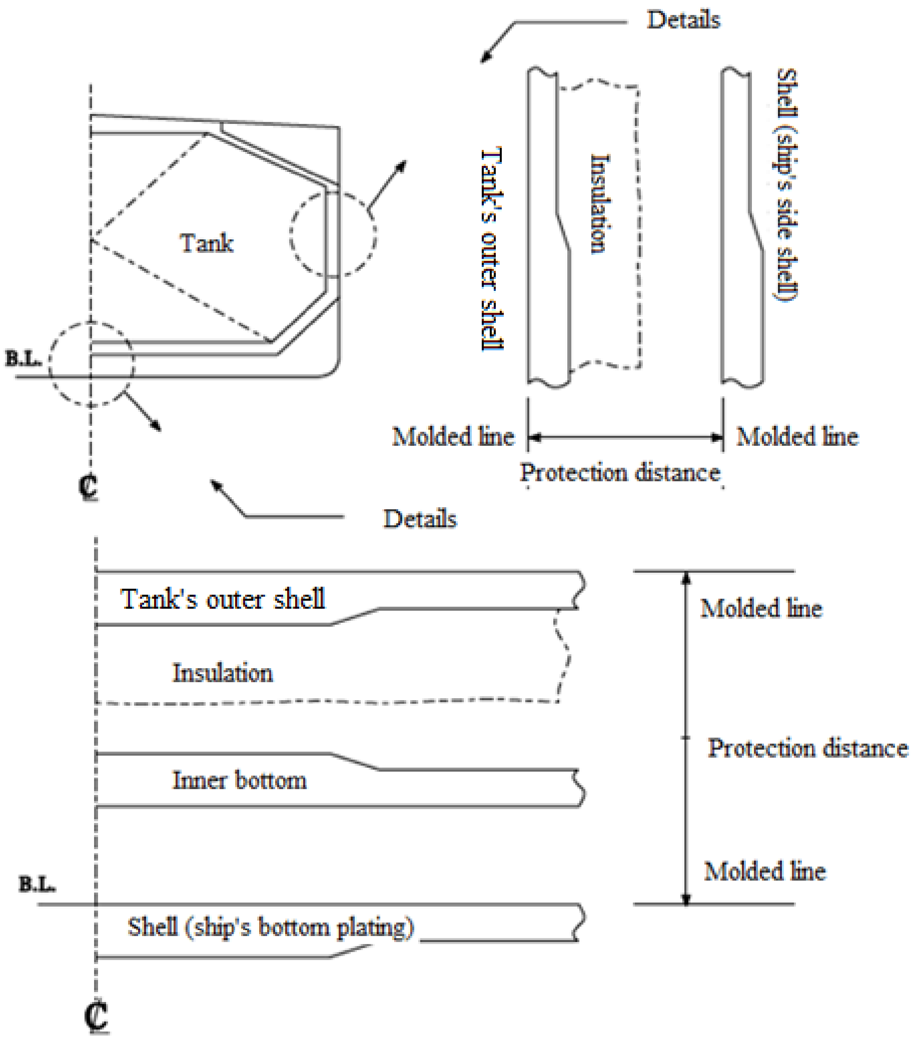
2.2.1.1 Fuel storage tanks are to be protected against mechanical damage.

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.

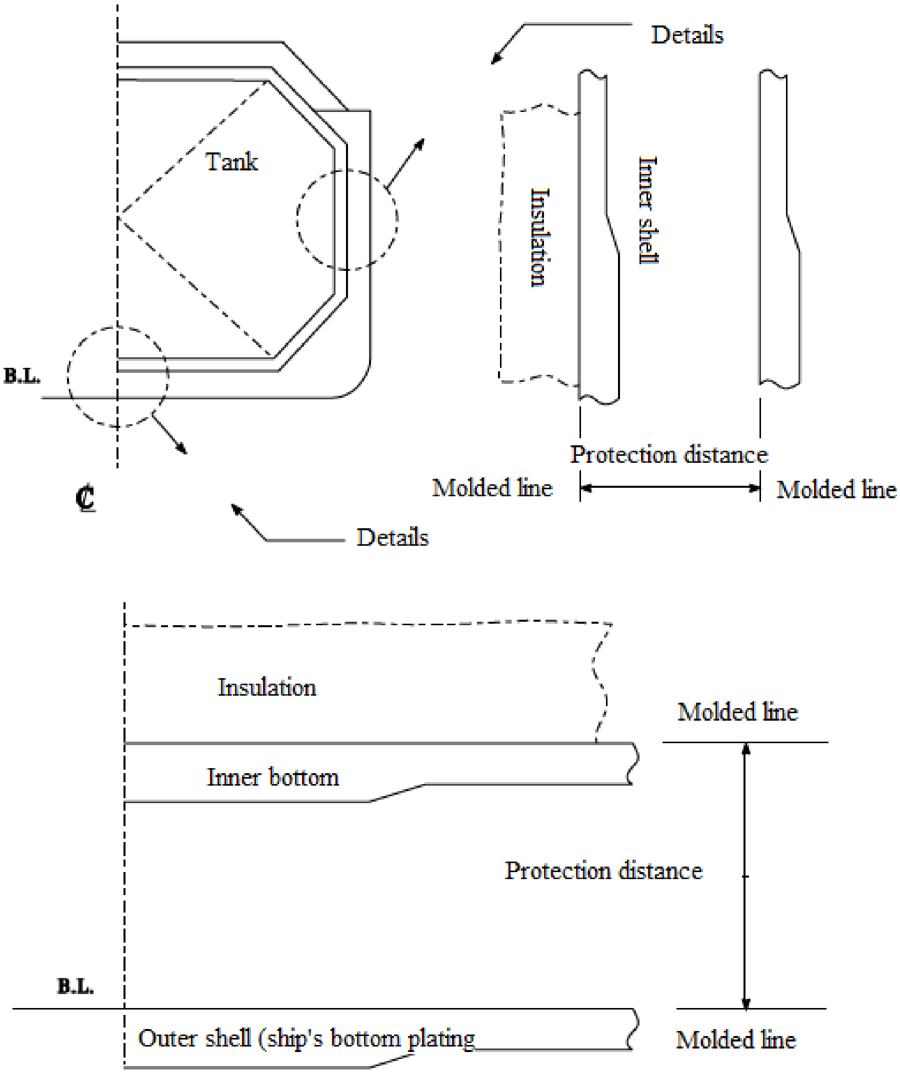
2.2.1.3 The fuel tank(s) is(are) be protected from external damage caused by collision or grounding in the following way:

(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.

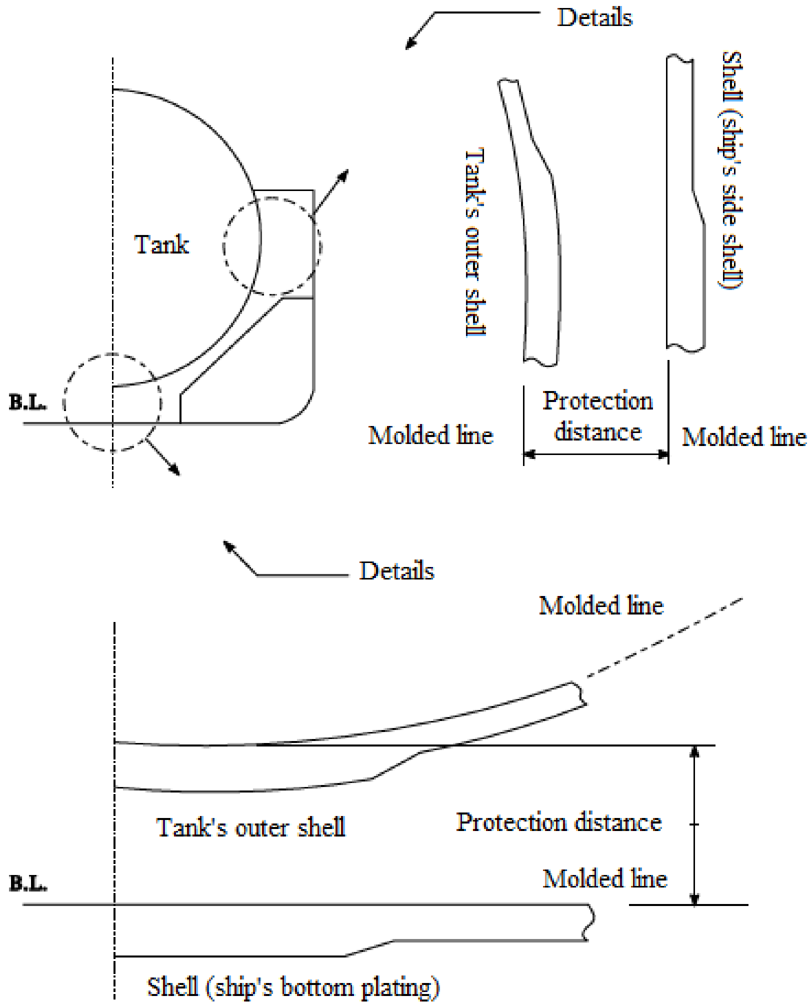
(2) For independent tanks, the protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance is to be measured to the bulkheads surrounding the tank insulation. The protective distances for various types of tanks see Figure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



(a) Independent prismatic tanks



(b) Membrane tanks



(c) Type C independent tanks

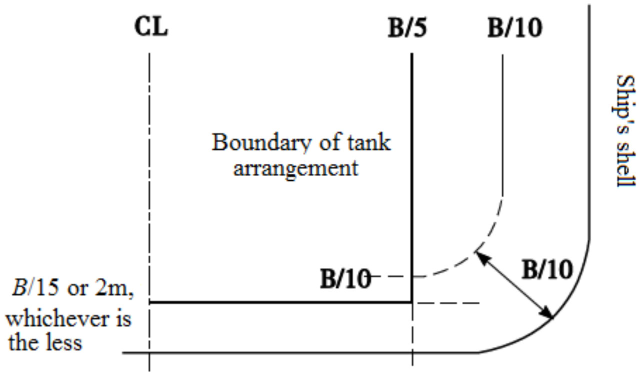
Figure 2.2.1.3 (2) Protective distances for various types of tanks

(3) For sea-going ships:

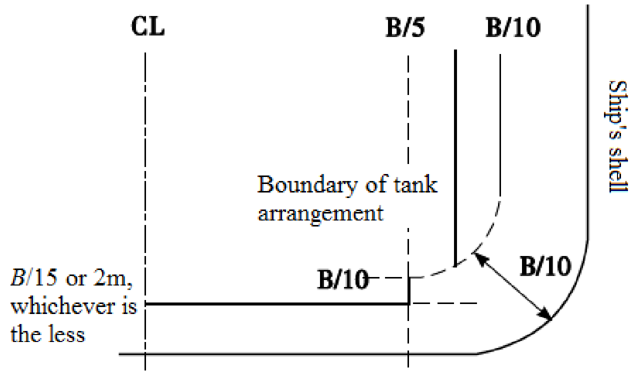
① The fuel tanks are to be located at a minimum distance of B/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught; where, B is the greatest moulded breadth of the ship at or below the deepest draught (summer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



(b) Protection distance for a probability method

Figure 2.2.1.3 (3) Arrangement of tanks of passenger ships

(b) For cargo ships:

for $V_c \leq 1000m^3$, 0.8m;

for $1000m^3 < V_c < 5000m^3$, $0.75 + V_c \times 0.2/4000m$;

for $5000m^3 \leq V_c < 30000m^3$, $0.8 + V_c/25000m$;

for $V_c \geq 30000m^3$, 2m.

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

③The 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 11.5 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 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 regulations may be specially considered in accordance with 1.1.5 OF the Rules.

2.2.1.4 For sea-going ships, the following calculating methods may be substituted for the provisions of 2.2.1.3 (3) ① of this Section:

(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 to be 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 aft most 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 should 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 to be used are:

If $(H\text{-}d) \leqslant 7.8$, $f_v = 1.0 - 0.8\frac{\mathrm{H-d}}{7.8}$ (f_v is not to be taken greater than 1.)

If $(H\text{-}d) > 7.8$, $f_v = 2.0 - 0.2\frac{(\mathrm{H-d})-7.8}{4.7}$ (f_v is not to be taken greater than 0.)

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

d——the deepest draught (summer load line draught).

(3) In case 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) for each fuel tank separately. The v 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, the calculations of f_{CN} are 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 and tank connection spaces are to be at least 10 m away from embarkation stations and assembly stations for survival craft and marine evacuation system and escape routes, provided that fuel tanks are located on the weather deck. If this is impracticable, effective insulation, such as water curtains, fire divisions or suitable screens, is to be provided between the fuel tanks and their tank connection spaces and the above locations, to prevent the persons in the above locations from damage due to a fire or leakage.*

2.2.1.7 *For ships carrying dangerous goods in packaged form, the distances between all kinds of dangerous goods and gas supply systems are to comply with the requirements for the insulation of this 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 tank is located in an enclosed space, a cofferdam is to be provided between the tank and the adjacent dangerous goods space. If the tank is located on the weather deck or in a semi-enclosed space, 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 by two or more tanks having the similar volumes. Where tanks are located in an enclosed space, the tanks mentioned above 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. If no cofferdam, an “A-60” class division is to be provided between the fuel storage hold spaces. If tanks are located on the weather deck, they are to be away from each other as far as practicable and 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. When 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 Design of machinery spaces

2.3.1.1 In order to minimize the probability of a gas explosion in a machinery space with gas consumer(s), 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 are 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 safety 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 are to be enclosed in a gas tight enclosure in accordance with 6.4.1.1 of the Rules.

2.3.3 ESD protected machinery spaces

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

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 detection;

(2) shutdown 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 machinery space with gas consumer(s) is to contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas consumer(s) 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 An ESD protected machinery space is to have a geometrical form to minimize the possibility of gas accumulation or any 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's side.

2.3.4.2 Fuel piping is 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 The fuel preparation room is to be provided and arranged according to the requirements for tank connection spaces unless it is located on the weather deck.

2.3.6 Bilge systems

2.3.6.1 The bilge system in the area where a LNG leakage may occur is to be independent of those of 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 are 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 affected from a spill is necessary.

2.3.7.2 Drip trays are to be made of suitable material.

2.3.7.3 The drip tray is to be thermally insulated from 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 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 the requirements of 2.3.7.2 to 2.3.7.5, 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's side by a pipe that preferably leads down near the sea.

2.3.7.7 *Additional measures such as a low-pressure water curtain, are to be fitted to provide for additional protection of the hull steel and the ship's side structure surrounding the drain pipe of the drip tray at the bunkering connection. The system is to supplement the requirements of 8.3.3 of Chapter 8 of the Rules and to run during fuel supply.*

2.3.8 Arrangement of entrances and other openings in enclosed spaces

2.3.8.1 No access of a non-hazardous area direct to a hazardous area is permitted. If necessary for the operation, 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 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 is to 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 to be 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 Air locks

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 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.

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 are not to be de-energized and are to be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems.

CHAPTER 3 MATERIALS 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 is related to functional requirements in 1.1.3.2 (1), (5), (6), (8), (9) and (10). In particular the following apply:

(1) Fuel piping are to be capable of absorbing 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 are to be fitted.

(4) Low temperature piping are 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 the other piping needed for a safe and reliable operation and maintenance are to be colour marked[7] in accordance with a standard accepted by CCS.

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

3.2.1.4 All pipes and fitting containing liquid gas, which may be isolated, are to be provided with pressure relief valves.

3.2.1.5 Pipes, which may contain low temperature fuel, are to be thermally insulated to an extent which will

[7] Refer to GB 3033 and EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

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.

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 If *metallic or non-metallic not covered in this Chapter are used in the piping, they 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:

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

where: t_0——theoretical thickness, in mm;

D——outside diameter, in mm;

K——allowable stresses, in N/mm^2; referred to in 3.2.4;

e——efficiency factory 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——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:

$b = \mathrm{D} \cdot \frac{t_0}{2.5r}$;

where, 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 provisions mentioned above, the minimum thickness of gas piping is to comply with the requirements of the Relevant Rules.*

3.2.3 Design conditions

3.2.3.1 The greater[8,9] of the following design conditions is to be used for piping, piping system and components:

(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 stresses

3.2.4.1 For pipes made of steel, including stainless steel, the allowable stress used in the formula of 3.2.2.1 is to be taken as the less:

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

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

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. 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 operations, 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 considered 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.

[8] 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.

[9] For ships on voyages of restricted duration, P0 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).

3.2.4.5 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 are to be carried out for each branch of the piping system.

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 ti comply with a standard acceptable to CCS, taking into account the design pressure defined in 3.2.3.1. 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) Flange 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 are to 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 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), 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. Bellows expansion joints are to be protected against mechanical damage. Flange connections are to be fitted with means against loosenning 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 regulations 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 0° C and down to minus 55° 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 6.4.13.1.1.2.

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°C		
CHEMICAL COMPOSITION AND HEAT TREATMEN		
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 REGULATIONS		
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) 27J	
Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J	
Test temperature	Thickness t (mm)	Test temperature (°C)
	$t \le 20$	0
	$20 < t \le 40$ [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.
2. Charpy V-notch impact tests are not required for pipes.
3. This Table is generally applicable for material thicknesses up to 40 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.

Note: ① For welded pressure pipes and materials for fuel tanks and process pressure vessels, the chemical compositions and mechanical properties are to complying with the requirements of Chapter 4 of CCS Rules for Materials and Welding.

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 55°C Maximum thickness 25 mm				
CHEMICAL COMPOSITION AND HEAT TREATMEN				
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%

To be continued

Optional additions: Alloys 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 REGULATIONS

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) 27J
Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J
Test temperature	5°C below the design temperature or -20°C whichever is lower

Notes:

1. The Charpy V-notch and chemistry regulations 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 (°C)
$25 < t \leqslant 30$	10°C below design temperature or -20°C whichever is lower
$30 < t \leqslant 35$	15°C below design temperature or -20°C whichever is lower
$35 < t \leqslant 40$	20°C below design temperature
$40 < t$	Temperature approved by CCS

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°C below design temperature or -20°C 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°C
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.

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with Table 3.3.1.1 (3) of this Chapter may be necessary.

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°C AND DOWN TO MINUS 165°C [2] Maximum thickness 25 mm		
Minimum design temp.(°C)	Chemical composition[5] and heat treatment	Impact test temp. (°C)
-60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP see note [6]	-65
-65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP see note [6,7]	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP see note [6,7]	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered[6, 7] and [8]	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered[6]	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated[9]	-196
-165	Aluminium alloys; 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 REGULATIONS

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 regulations for design temperatures below –165°C 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 (°C)
$25< t \leqslant 30$	10°C below design temperature
$30< t \leqslant 35$	15°C below design temperature
$35< t \leqslant 40$	20°C 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.

4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
5. The composition limits are to be in accordance with Recognized Standards.
6. Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by CCS.
7. A lower minimum design temperature for quenched and tempered steels 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°C, provided that the impact tests are carried out at –196°C.
9. The impact test may be omitted subject to agreement with CCS.

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°C AND DOWN TO MINUS 165°C[3] Maximum thickness 25 mm			
Minimum design temp.(°C)	Chemical composition[5] and heat treatment	Impact test	
		Test temp. (°C)	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 or normalized and tempered or quenched and tempered6, 7 and 8	-70	34
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered6, 7 and 8	-95	34
-165	9% nickel steel – double normalized and tempered or quenched and tempered6	-196	41
	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated.[8]	-196	41
	Aluminium alloys; such as type 5083 annealed		Not required
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS			
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 regulations for forgings and castings may be subject to special consideration by CCS.
3. The regulations for design temperatures below –165°C are to be specially agreed with CCS.
4. The test temperature is to be 5°C below the design temperature or -20°C 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 STRUCTURES REQUIRED BY 4.2.11.1 (2)								
Minimum design temperature of hull structure (°C)	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

To be continued

down to -20	×	×	20	50	×	30	50	50
down to -30	×	×	×	40	×	20	40	50
Below -30	In accordance with table 7.2 except that the thickness limitation given in table 7.2 and in footnote 2 of that table does not apply.							
Note: 'x' means steel grade not to be used.								

3.3.1.2 Materials having a melting point below 925°C 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 fulfil the material regulations for pipe materials with design temperature down to minus 55°C 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 fulfil the material regulations for pipe materials with design temperature down to minus 165°C in Table 3.3.1.1 (4).

3.3.2 Non-metallic materials

3.3.2.1 *Non-metallic materials are to be chosen and used according to the relevant requirements of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and PART 2 of CCS Rules for Materials and Welding.*

CHAPTER 4 FULE CONTAINMENT SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 Goal

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

4.1.2 Functional requirements

4.1.2.1 This Chapter is related to functional requirements in 1.1.3.2 (1), (2), (5) and (8) to (17) . In particular the following is to 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 are to 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 permanent installed tanks as described in this chapter.

4.1.3 General requirements

4.1.3.1 The MARVS of a fuel tank is not to be greater than *1.2 MPa for inland waterways ships* and 1.0 MPa for sea-going ships.

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

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

4.1.3.4 All tank connections, fittings, flanges and tank valves are to be enclosed in gas tight 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 storage 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.

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

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 A tank and the pipe of the first of its associated stop valves are to provide an equivalent level of safety as the tank and to be protected according to 4.1.3.13 or 4.1.3.14.

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 build up 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 and the maximum potential evaporation does not exceed the ventilation volume, the built-up pressure mentioned in 4.1.3.10 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 maximum amount of leakage into the tank connection space is to be determined according to the detailed design and detection and closing system.

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

4.1.3.14 *Secondary barriers may not be required when the pipes mentioned in 4.1.3.13 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.

4.1.3.17 *Finite element analysis is to be carried out to assess the strength of the hull structures within the tank area. The criterion for modelling, loading conditions, tank supporting and hull structures are to comply with the relevant requirements of 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. The criterion for the tank structure is to comply with the requirements of 4.2.14 and 4.2.15 of the Rules.*

Section 2 LNG FUEL CONTAINMENT SYSTEMS

4.2.1 General requirements

4.2.1.1 Risk assessment is to be carried out for LNG fuel containment systems of novel design not being compliance with this Chapter.

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 liquefied gas fuel containment system's design life 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 liquefied gas fuel containment system structural strength 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. 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 thermally induced 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 accident 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) 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 is to sustain without rupture the rise in internal pressure specified in 4.5.3.1 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) 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, catholic 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 fuel containment system's life 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).

4.2.1.9 Fuel containment systems are to be provided with adequate means of access to areas that need inspection as specified in the inspection/survey plan. Fuel containment systems, including all associated internal equipment are to be designed and built to ensure safety during operations, inspection 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 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 the weather deck or in the semi-enclosed space, all openings of the inner shell are to be above the potential highest liquid level, and the outer shell needs not meet the requirements specified in (1) above.*

4.2.2.6 For independent tanks requiring full or partial secondary barrier, means for safely disposing of leakages from the tank are 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 tank	Complete secondary barrier
Independent tank	
Type A	Complete secondary barrier
Type B	Partial secondary barrier
Type C	No secondary barrier required

4.2.3.2 Secondary barriers, including a spray shield (if any), are to comply with the following requirements:

（1）it is to be 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);

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

4.2.3.3 Partial secondary barriers are to be used with a small leak protection system and meet all the regulations in 4.2.3.2. 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 the Rules.

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 fulfil its functional requirements at a nominal static angle of trim.

4.2.4 Supporting structures

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, 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 The supports and supporting units are to be subjected to the loads specified in 4.2.7.3 (3) ⑧ and 4.2.7.5. 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, the tank saddle is to be made of low temperature materials and the connection of the saddle to the hull base is to be thermally insulated, provided that the tank shell is made of low temperature materials.*

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 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 is 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, thermal insulation, 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 slashing;

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, 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°C 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 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) (*Pgdsite*) max is the associated liquid pressure determined using site specific accelerations

(c) *Peq* is to be the greater of *Peq1* and *Peq2* calculated as follows:

$$Peq1 = Po + (Pgd)\max \quad \text{MPa}$$

$$Peq2 = Ph + (Pgdsite)\ max \quad \text{MPa}$$

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). The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations are to be calculated as follows:

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

where: a_β——dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction. 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, 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

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

ρ——maximum liquefied gas fuel density (kg/m3) at the design temperature.

The direction that gives the maximum value （P_{gd}) max or (P_{gdsite}) 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). The above formula applies only to full tanks.

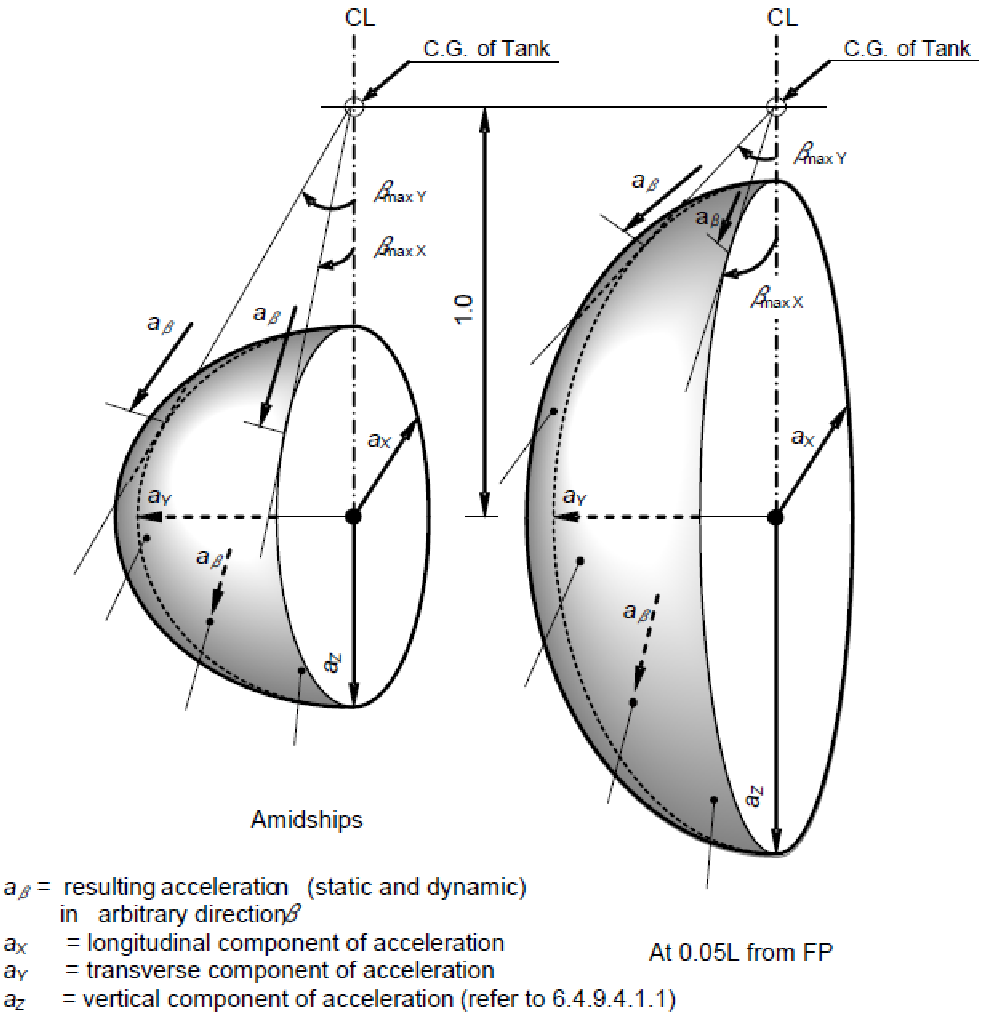


Figure 4.2.7.3 (4) (a) Acceleration ellipsoid

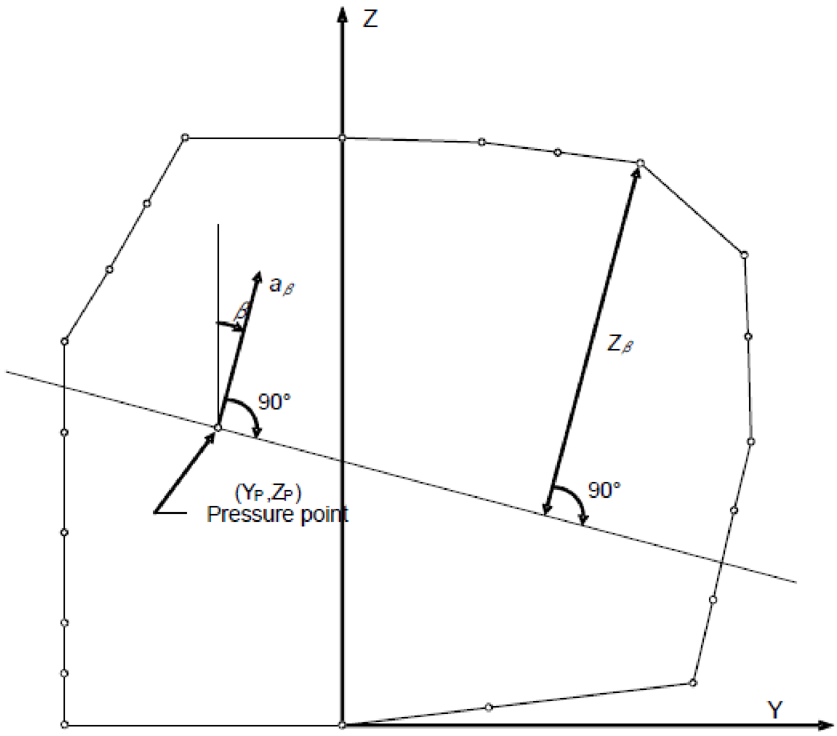


Figure 4.2.7.3 (4) (b) Determination of internal pressure heads

(5) External loads

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)Thermal loads

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

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

(7) Vibration

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

(8) Interaction loads

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

(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 liquefied gas fuel containment system referred to Section 5 of Chapter 13.

(11) Static heel loads

Loads corresponding to the most unfavourable static heel angle within the range 0°to 30°are to be considered for sea-going ships; *and Loads corresponding to the most unfavourable static heel angle within the range 0°to 20°are to be considered for inland waterways ships.*

(12) Other loads

Any other loads not specifically addressed, which could have an effect on the liquefied gas 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's 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 proposed and approved by CCS.

③ *For sea-going ships, the values of acceleration components in three directions may be calculated according to 4.28.2 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.*

④ *For inland waterways ships, the minimum component of acceleration according caused by the pontoon's motion is to be determined according to one of the following methods: Method 1:*

(a) *Longitudinal acceleration a_x is to be specified in 4.2.7.5 (1) of this Chapter;*

(b)*Transversal acceleration a_y is to comply with the requirements for transversal accelerations of containers during the securing calculation of CCS Rules for the Construction of Inland Waterways Steel Ships;*

(c)*Vertical acceleration a_z is to comply with the requirements for vertical accelerations of containers during the securing calculation of CCS Rules for the Construction of Inland Waterways Steel Ships;*

Method 2:

(a) *longitudinal acceleration: 2g;*

(b) *transversal acceleration: 1g;*

(c) *straight up acceleration: 1g;*

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

⑤ Ships for restricted service may be given special consideration by CCS.

(2)Interaction loads

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

(3) Sloshing loads

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

(4)Snow and ice loads Snow and icing are 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)Account is to be taken to loads due to water on deck. (7)Account is to be taken to wind generated loads as relevant.

4.2.7.5 Accidental loads

(1)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＞100m	$0.5g$
60＜L≤100m	$\left(2-\frac{3(L-60)}{80}\right)g$
L≤60m	$2g$

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

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 liquefied gas fuel containment systems can be demonstrated by compliance with 4.2.13 to 4.2.16, as appropriate for the liquefied gas fuel containment system type.

4.2.8.3 For other liquefied gas fuel containment system types, that are of novel design or differ significantly from those covered by 4.2.13 to 4.2.16, 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 accepted 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 liquefied gas fuel containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously are to be considered.

(2) The most unfavourable scenarios 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:

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

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

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

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

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

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

where, $\alpha_{x.st}$, $\alpha_{y.st}$, $\alpha_{z.st}$, $\alpha_{xy.st}$, $\alpha_{xz.st}$ and $\alpha_{yz.st}$ ---static stresses;

$\alpha_{x.dyn}$, $\alpha_{y.dyn}$, $\alpha_{z.dyn}$, $\alpha_{xy.dtn}$, $\alpha_{xz.dyn}$ and $\alpha_{yz.dyn}$ --- dynamic stresses.

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.

4.2.10.1 Ultimate design conditions

(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:

①R_e = specified minimum yield stress at room temperature (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 (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 alloys, 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 liquefied gas 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:

$$\alpha_c = \sqrt{\alpha_x^2 + \alpha_y^2 + \alpha_z^2 - \alpha_x\alpha_y - \alpha_x\alpha_z - \alpha_y\alpha_z + 3\left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)}$$

where: α_x --- total normal stress in x-direction;

α_y --- total normal stress in y-direction;

α_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 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 conditions

(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:

$$\sum \frac{n_i}{N_i} + \frac{n_{loading}}{N_{loading}} \le C_w$$

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;

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 liquefied gas fuel containment system is to be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the liquefied gas 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 Cw values specified in 4.2.10.2(12) to 4.2.10.2(14).

(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 loading spectra includes 8 cyclic loading, each of its cyclic loads ±P and its corresponding number of cycles n_i are to be calculated by the following formula:*

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

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

where: i---i=1, 2, 3, 4, 5, 6, 7, 8;

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

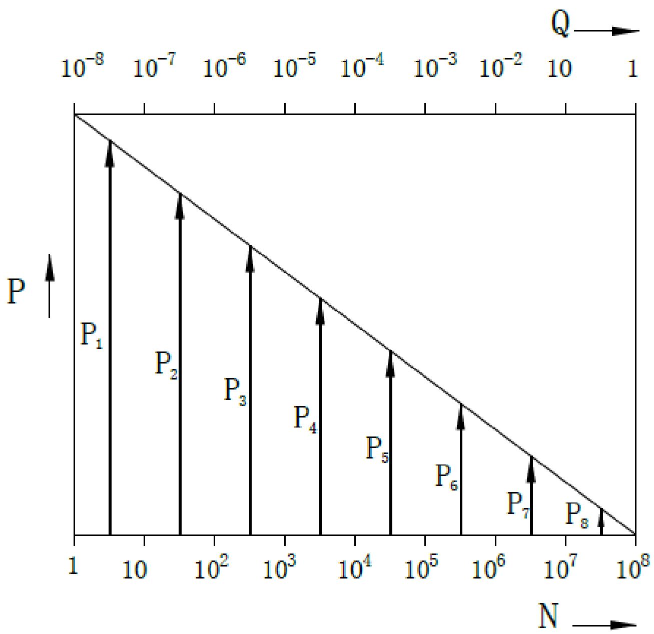


Figure 4.2.10.2 (6) Long-term distribution loading spectra

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, 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), 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 are 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 analysing 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) Crack propagation analysis specified in 4.2.10.2(12) 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).

(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 regulations 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:

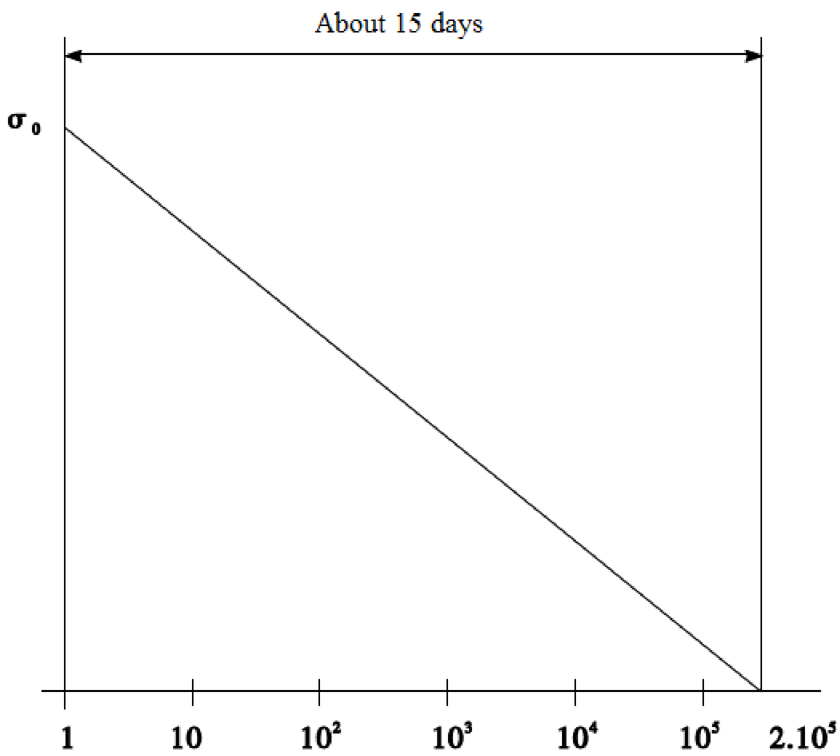
C_w is to be less than or equal to 0.5.

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 (3) 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 are 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 (3) times the lifetime of the tank.



Response cycles

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

The supports and supporting units are to be subjected to the loads specified in 4.2.7.3 (3) ⑧ and 4.2.7.5. These loads 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 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), provided the heating arrangements are in compliance with 4.2.11.1(4).

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°C, due to the influence of liquefied gas fuel temperature, is to be in accordance with Table 3.3.1.1(5). This includes hull structure supporting the liquefied gas 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). 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) where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of plus 5°C for air and 0°C for seawater with no credit taken in the calculations for heating; and

③ as an alternative to ② above, for longitudinal bulkhead between liquefied gas fuel tanks, credit may be taken for heating provided the material remain suitable for a minimum design temperature of minus 30°C, or a temperature 30°C lower than that determined by 4.2.1.1(1) with the heating considered, 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) are 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.

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 ageing;

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°C below the minimum design temperature, but not lower than minus 196°C.

(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 liquefied gas fuel containment systems

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

(2)Thermal insulation and other materials used in liquefied gas 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 ageing;

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°C below the minimum design temperature, but not lower than minus 196°C.

(4) Due to location or environmental conditions, thermal insulation materials are to have suitable properties of resistance to fire and flame spread and is 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.

(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[10]. 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 in accordance with the requirements of CCS. 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.

4.2.13.2 Structural analysis

(1) Consideration is to be given to the internal pressure and the interaction loads between the liquefied gas fuel tank with its supporting and keying system and the reasonable part of the hull mentioned in 4.2.7.3(3) for the structural analysis.

(2) For parts, such as structure in way of supports, not otherwise covered by 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 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. These loads need not be combined with each other or with environmental loads.

4.2.13.3 Ultimate design conditions

(1) For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and

[10] 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.

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 Re/1.33 for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and Re are defined in 4.2.10.1(4). 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 tensional deformation as well as the hull/liquefied gas fuel tank interaction forces due to the deflection of the hull structure and liquefied gas fuel tank bottoms.

(2) Tank boundary scantlings are to meet at least the requirements of CCS for deep tanks taking into account the internal pressure as indicated in 4.2.7.3(3)① and any corrosion allowance required by 4.2.1.7.

(3) The liquefied gas 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), 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 protection system is to be provided. The small leak protection system is to be designed according to 4.2.3.

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, are to be carried out.

(3) A three-dimensional analysis is to be carried out to evaluate the stress levels, including interaction with the ship's 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 conditions

(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);

F --- the lesser of (R_m / C) or (R_e / D).

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

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

Table 4.2.14.3 (2)

	Nickel steels and carbon	**Austenitic steel**	**Aluminium alloys**
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 considered in acceptance with CCS.

(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 steels and carbon-manganese steels, the lesser of R_m /2 or R_e /1.2;

② for austenitic steels, the lesser of R_m /2.5 or Re /1.2; and

③ for aluminium alloys, the lesser of R_m /2.5 or Re /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 CCS.

(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 conditions

(1) Fatigue and crack propagation assessment is to be performed in accordance with the provisions of 4.2.10.2. The acceptance criterion is to comply with 4.2.10.2（12）、4.2.10.2（13） or 4.2.10.2（14）, 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), 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 4.2.14.3, modified as appropriate taking into account their lower probability of occurrence.

4.2.14.6 The required 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:

$$S_1 \leq 0.5\sqrt{Rt} \quad \text{and}$$

$$S_2 \geq 2.5\sqrt{Rt}$$

where: S_1 --- distance in the meridional direction over which the equivalent stress exceeds 1.1*f*;

S_2 --- distance in the meridional direction to another region where the limits for primary general membrane stress a e 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 modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in 4.2.15.1（2）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:

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

where:

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

where: σ_m --- design primary membrane stress;

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

55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel; 25 N/mm^2 for aluminium alloy (5083-O);

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

$$h,\ 0.75b \text{ or } 0.45l$$

where: h--- height of tank (dimension in ship's vertical direction) (m);

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

l--- length of tank (dimension in ship's longitudinal direction) (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) is to be considered as a minimum thickness after forming, without any negative tolerance;

② for pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, is not to be less than 5mm for carbon manganese steels and nickel steels, 3 mm for austenitic steels or 3mm for aluminium alloys or 7 mm for aluminium alloys;

③ the welded joint efficiency factor to be used in the calculation according to 4.2.15.2(4) 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) 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 P4 = 0.

(4) The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 4.2.7.3(3), 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 a4.2.15.2 (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; and

(c) secondary stresses and thermal stresses are to be specially considered.

4.2.15.3 Ultimate design conditions

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

$$\sigma_m \le f$$

$$\sigma_L \le 1.5f$$

$$\sigma_b \le 1.5f$$

$$\sigma_L + \sigma_b \le 1.5f$$

$$\sigma_m + \sigma_b \le 1.5f$$

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

$$\sigma_L + \sigma_b + \sigma_g \le 3.0f$$

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).

R_m and R_e are the same as those defined above. With regard to the stresses σ_m, σ_b, σ_L and σ_g see also the definition of stress categories defined above. The values A and B are to have at least the following minimum values:

Table 4.2.15.3 (1)

	Nickel steels and carbon -	Austenitic steel	Aluminium alloys
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 conditions

(1) For type C independent tanks, CCS may require additional verification to check their compliance with 4.2.15.1(1), 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), 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 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).

③ Complete secondary barrier The secondary barrier is to be designed according to 4.2.3.

④ The design vapour pressure P_0 is not normally 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 is to be sufficient to allow for effective means of gas detection.

4.2.16.2 Design basis

(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 Accident 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 4.2.16.1②.

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 inter barrier 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 analysis

(1)Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the liquefied gas fuel containment and associated structures and equipment noted in 6.4.7 are be performed. The structural analysis is to provide the data required to assess each failure mode that has been identified as critical for the liquefied gas 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. 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) are to be based on the particular motions, accelerations and response of ships and liquefied gas 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, for in-service conditions.

(2) The choice of strength acceptance criteria for the failure modes of the liquefied gas 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 regulations for deep tanks, taking into account the internal pressure as indicated in 4.2.7.3 (3) ① and the specified appropriate regulations for sloshing load as defined in 4.2.7.4 (3).

4.2.16.6 Fatigue design conditions

(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, with relevant regulations depending on:

① the significance of the structural components with respect to structural integrity; and

② availability for inspection.

(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 inspection, 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 regulations stated in 4.2.10.2 (13).

(5) Structural elements not accessible for in-service inspection, 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 regulations stated in 4.2.10.2 (14).

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. 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 are to be designed according to 4.2.1 to 4.2.12, 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.

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. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.

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.

Section 3 PORTABLE LIQUEFIED GAS FUEL TANKS

4.3.1 General requirements

4.3.1.1 Liquefied gas fuel tanks are to be designed in accordance with 4.2.15. 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 operations;

(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 fuel tanks are to be secured to the deck while connected to the 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's stability.

4.3.1.5 Connections to the ship's fuel piping systems are to be made by means of approved flexible hoses 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.

4.3.1.7 The pressure relief system of portable tanks is to be connected to a fixed venting system.

4.3.1.8 Control and monitoring systems for portable fuel tanks are to be integrated in the ship's control and monitoring system. The safety system for portable fuel tanks is to be integrated in the ship's 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's fuel piping system,

(1) with the exception of the pressure relief system in 4.3.1.7, each portable tank is to be capable of being isolated at any time;

(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 *If a LNG tank container is used as a portable fuel tank, it is also to comply with the following requirements:*

(1) *The design, construction and testing are to comply with the relevant requirements of CCS Rules for Certification of Freight Containers and recognized standards*[11] *accepted by CCS.*

(2) *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 report is 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.

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 to be provided with suitable

[11] Such as JB/T 4784 Tank Containers for Cryogenic Liquid and International Maritime Dangerous Goods Code (IMDG Code).

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 to be installed in the enclosed spaces containing the CNG storage. Special consideration is to be given to the extinguishing of jet-fires.

Section 5 RESSURE 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, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, are also to be provided with a suitable pressure relief system.

4.5.1.2 Pressure release systems of a tank is to be independent of the pressure control system specified in Section 7 of this Chapter and other functional piping.

4.5.1.3 Fuel storage 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 fuel 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 the following requirements are to be meted:

(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 CCS for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.

4.5.2.2 Liquefied gas 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 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 regulations apply to PRVs fitted to pressure relief systems:

(1) PRVs on fuel tanks with a design temperature below 0oC 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 a fuel tank PRV, a safe means of emergency isolation is to be available.

(1) procedures are to be provided 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's log, and at the PRV.

4.5.2.7 Each pressure relief valve installed on a liquefied gas fuel 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; and

(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 working areas and walkways (if applicable) after assessment.

4.5.2.8 The outlet from the pressure relief valves is to normally 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 machinery installations.

If this is impracticable for inland waterways ships, the distance mentioned above may be reduced from 10 m to 5 m after assessment.

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. 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 are 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 relief systems

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 liquefied gas fuel tank pressure above the MARVS:

① the maximum capacity of the liquefied gas fuel tank inerting system if the maximum attainable working pressure of the liquefied gas fuel tank inerting system exceeds the MARVS of the liquefied gas fuel tanks; or

② vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0.82} \qquad \mathrm{m^3/s}$$

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 liquefied gas fuel 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 fireproofing 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:

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

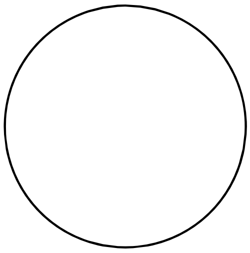
where:

k--- ratio of specific heats at relieving conditions, and the value of which is between 1.0 and 2.2. If *k* is not known, D = 0.606 is to be used;

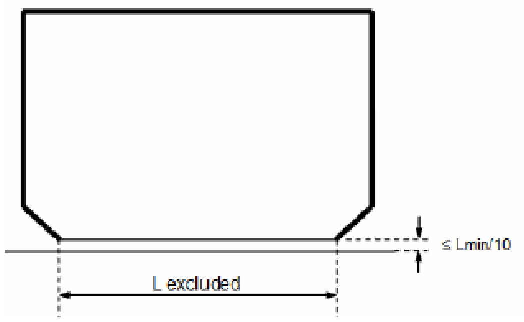
Z--- compressibility factor of the gas at relieving conditions; if not known, *Z* = 1.0 is to be used;

M--- molecular mass of the product.

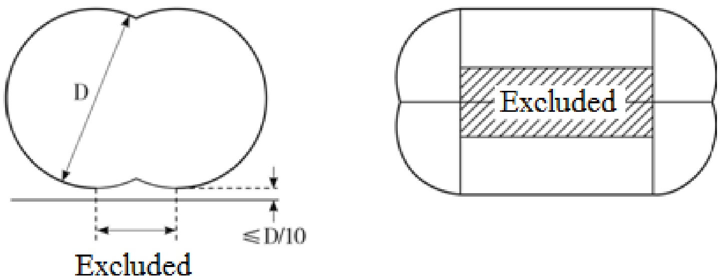
A---external surface area of the tank, in m^2, as for different tank types, as shown in Figure 4.5.3.1 (1).



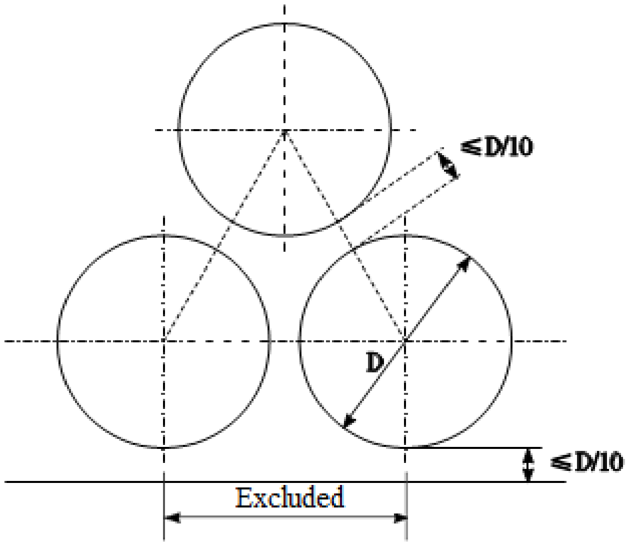
Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks



Prismatic tanks



Bilobe tanks



Horizontal cylindrical tanks arrangement

Figure 4.5.3.1 (1)

③ For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by coffer dams 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 factors according may be reduced to the following values:

F=0.5 to F=0.25

F=0.2 to F=0.1

The minimum fire factor is F=0.1

④ The required mass flow of air at relieving conditions is given by:

$$M_{air} = Q \cdot \rho_{air} \quad \text{kg/s}$$

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.

(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;

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 LIQUEFIED GAS FUEL TANKS

4.6.1 General requirements

4.6.1.1 A loading limit curve for actual fuel loading temperatures is to be prepared from the following formula:

$$LL = FL\rho_R / \rho_L$$

where: LL --- loading limit as defined in 2.2.27, expressed in per cent;

FL --- filling limit as defined in 2.2.16 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 small 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%. This also applies in cases where a second system for pressure maintenance is installed, (refer to Section 7 of this Chapter). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in 4.6.1.1 is to be used.

Section 7 MAINTAINING OF FUEL STORAGE CONDITON

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, liquefied gas fuel tanks' 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.

4.7.2 Design of systems

4.7.2.1 For worldwide service, the upper ambient design temperature is to be sea 32℃ and air 45℃. For service in particularly hot or cold zones, these design temperatures are to be increased or decreased, to 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. 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 operations 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 regulations 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 is 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. If they have a capacity in excess of 25% of the largest required capacity for pressure control, they can be repaired on board without external sources.

Section 8 ATMOSPHERIC CONTROL WITHIN THE FUEL CONTAINMENT SYSTEM

4.8.1 General requirements

4.8.1.1 A piping system is to be provided to enable each tank to be safely gas-freed and purged and be safely refuelled after gas-freeing. 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 liquefied gas 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 are 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 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 Environment control of spaces surrounding type C independent tanks

4.8.3.1 Spaces surrounding liquefied gas fuel tanks 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 for 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 space, 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.

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 is to be fitted with an alarm set at a maximum of 5% oxygen content by volume. A low oxygen alarm is to be fitted.

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.

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 can be conducted without causing danger to persons, 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) . In particular the following is to 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 *A portable means of communication is to be provided between the ships, 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 The bunkering station is to be located on open deck so that sufficient natural ventilation is provided. Enclosed or semi-enclosed bunkering stations are to be subject to the risk assessment, and the relevant report is to be approved by CCS.

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 process the leakage, such as a pipe that preferably leads down near the sea through which LNG will be drained over the ship's side. Drip trays are to comply with the relevant requirements of 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 *During 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 can be subjected to during bunkering.

5.2.3 Manifolds

5.2.3.1 The bunkering manifold is 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 *Bunkering connections are to comply with the relevant requirements of of CCS Rules for Liquefied Natural Gas Bunkering Ships.*

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 flammable gas is discharged to the atmosphere during filling of storage tanks.

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 are 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 operations and/or from another safe location.

5.3.1.4 Means are to be provided for draining any fuel from the bunkering pipes upon completion of 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 not demonstrated to be required at a higher value due to pressure surge considerations, a default time as calculated in accordance with 13.7.3.8 from the trigger of the alarm to full closure of the remote operated valve required by 5.3.1.3 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 the requirements of 3.2.1.3 of Chapter 3 of the Rules.*

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 arranged in accordance with the requirements for those of gas supply piping of the Rules. Ventilation and gas detection are to be continually carried out during the bunkering operation. In case of loss of ventilation or on detection of gas, an audible and visual alarm is to be given at the bunkering control location.*

CHAPTER 6 GAS FUEL SUPPLY

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), 1.1.3.2(8) to (11) and 1.1.3.2(13) to (17) . In particular the following is to 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 inspection;

(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

(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 are 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 type C independent tank, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

6.1.3.4 *Where two or more type C independent tanks are fitted and each of them is fitted with a tank connection space, they may be located in one compartment.*

6.1.3.5 *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 engine 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.

6.1.3.6 For passenger ships required to meet the requirements for safe return to port, the gas supply systems or oil supply systems of the same power system are to be independent, and it is to be ensured that the gas or oil supply to the power system is in order in case of a fire or flooding of any compartment.

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 operation[12] 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 12.4.3 of Chapter 12 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 are 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 be capable of automatically shutting off the gas supply piping in accordance with Table 12.4.3 of the Rules, and operating from a safe location in the escape route of the engine room, central control room of the engine room (if applicable) and navigation bridge and outside the machinery space. 6.2.1.5 A double block and bleed valve is to be fitted in the gas supply line to each gas engine, which is to be arranged according to the following requirements:

(1) A set of two valves are to be fitted in series in the gas pipe to the engine, and the third valve is to be fitted in the venting pipe between those two valves. The venting pipe is to lead to a safe location in the open air.

(2) A failure mentioned in Table 12.4.3 of the Rules will 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 be automatically opened when the faults mentioned in Table 12.4.2 and Table 12.4.3 of the Rules occur;

(4) *Those three valves are to be reset manually;*

(5) The two valves are to be of the fail-to-close type, while the ventilation valve is to be fail-to-open.

(6) A failure mentioned in Table 12.4.3 of the Rules will cause the shutoff valves that are in series to

[12] Normal operation in this context is when gas is supplied to consumers and during bunkering operations.

close automatically and the bleed valve to open 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, the gas supply piping between the master gas fuel valve and the double block and bleed valve and the gas supply piping between the double block and bleed valve and the injection valve of the engine are to be automatically ventilated.*

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 assure safe isolation during maintenance on the engine.

6.2.1.9 Where a separate master valve is provided for each 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 arrangement of gas supply valves of single-engine installations and multi-engine installations are shown in Figure 6.2.19 (a) and Figure 6.2.1.9 (b).

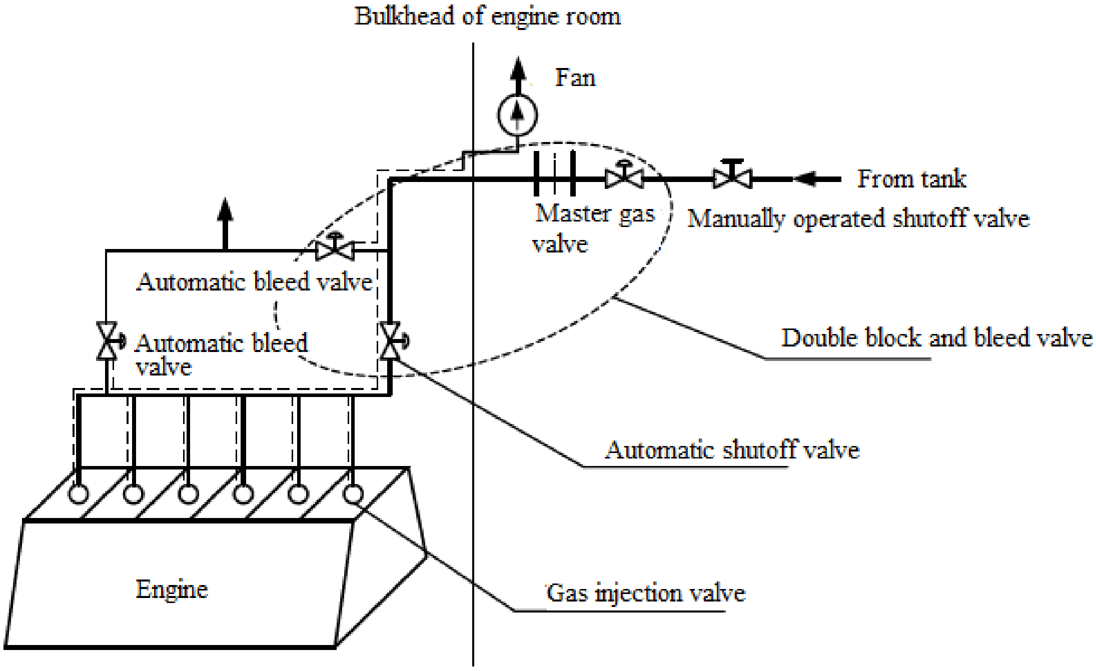
6.2.1.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations, means are to be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected, a valve is to be automatically shut off[13].

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 gas fuel valve. *Means of detection accepted by CCS include, but are not limited to:*

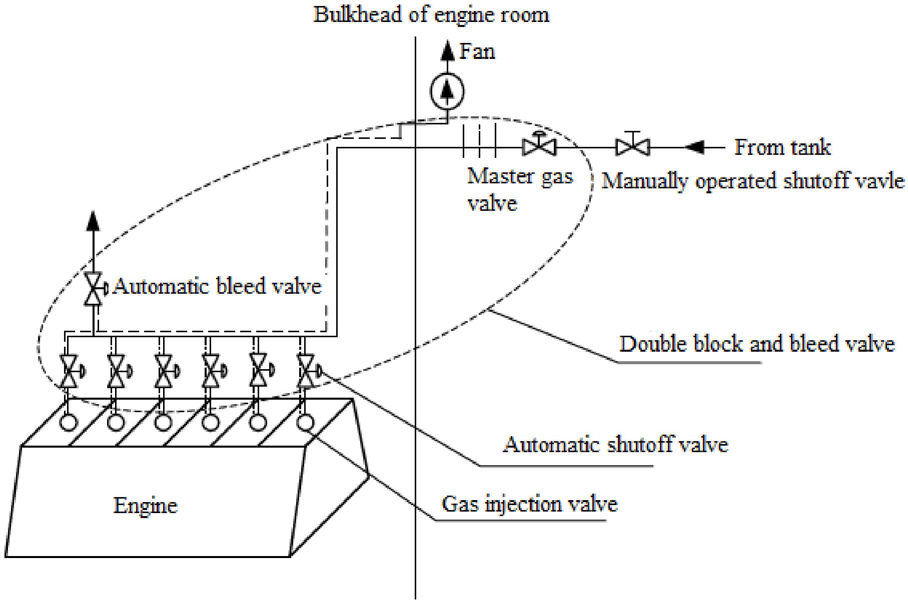
(1) a combined excess flow detector with automatic stop valve located close to the point of entry to the engine room; or

(2) a low pressure detector located at the engine inlet.

[13] The shutdown is to be time delayed to prevent shutdown due to transient load variations.

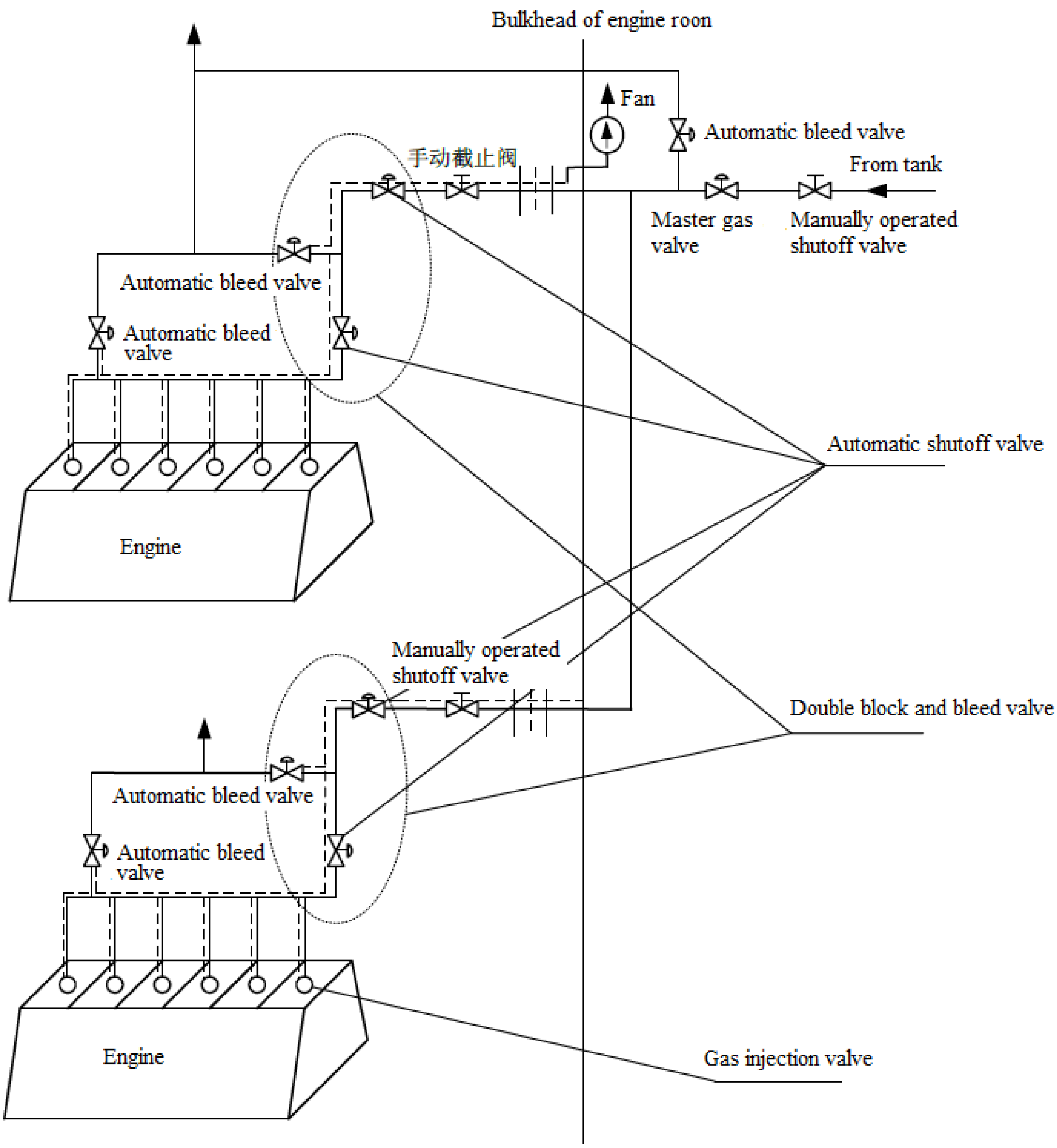


Arrangement ①



Arrangement ②

Figure 6.2.1.9 (a) Arrangement of gas supply valves of single-engine systems



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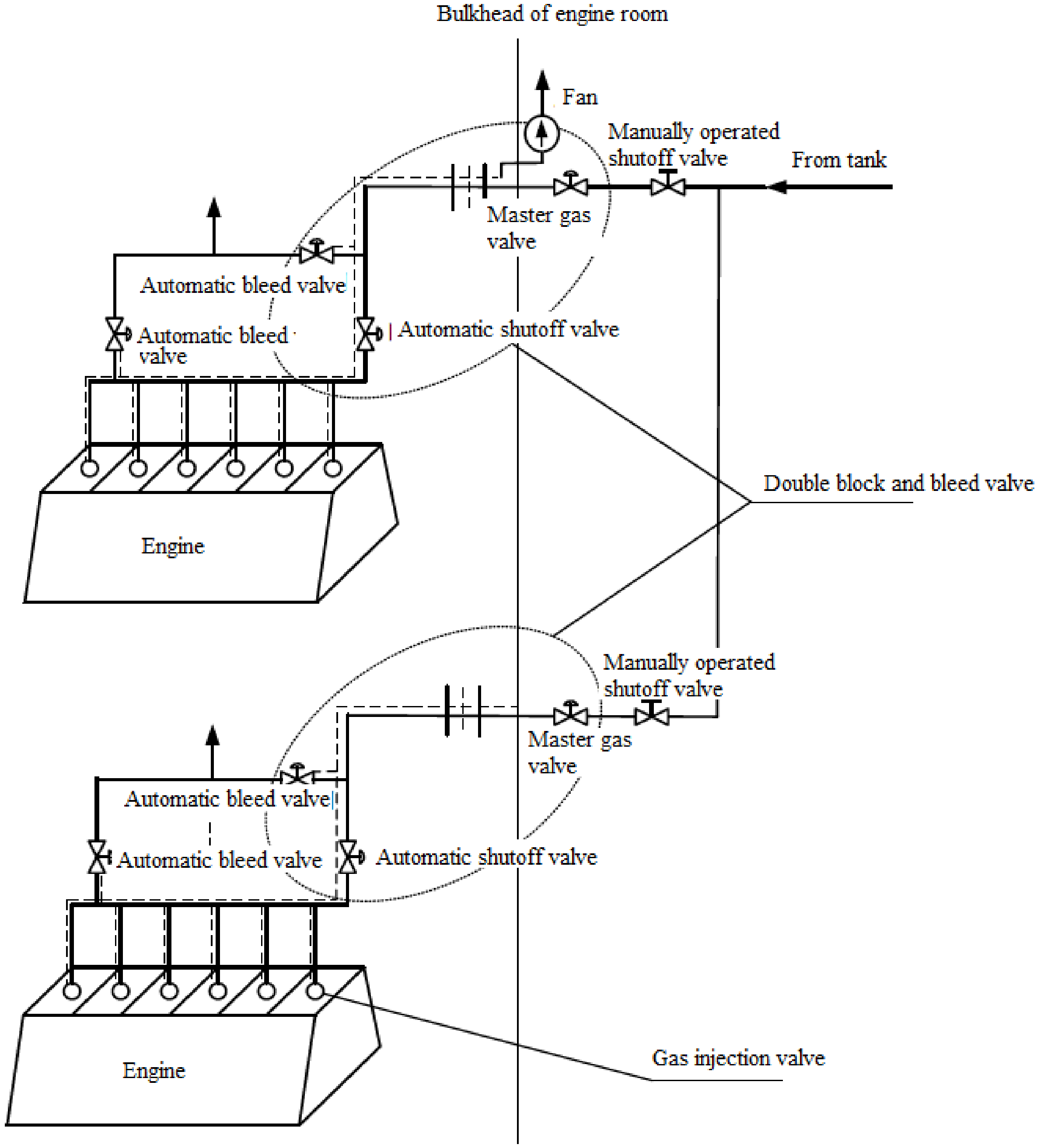

Arrangement ②

Figure 6.2.1.9 (b) Arrangement of gas supply valves of multi-engine systems

Section 3 SUPPLY SYSTEMS OUTSIDE THE MACHINERY SPACE

6.3.1 General requirements

6.3.1.1 Where the gas supply piping needs to pass through an enclosed space other than those specified in 2.3.4.2 of the Rules, it is to be double wall piping. Double wall piping is to be mechanically underpressure ventilated with 30 air changes per hour, and gas detection as required in 12.3.1 of the Rules is to be provided. Other solutions providing an equivalent safety level may also be accepted by CCS.

6.3.1.2 The requirement in 6.3.1.1 need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

6.3.1.3 The design pressure of the double wall pipe in an enclosed space is to comply with 6.4.1.3 and 6.4.1.4, as applicable.

6.3.1.4 A high pressure gas supply line installed outside the engine room is to be protected to minimize the risk injury to personnel in case of rupture.

6.3.1.5 Gas supply piping is not to pass through special category spaces, ro-ro spaces and vehicle spaces. If this is impracticable, the gas supply piping is to be double wall piping, and effective means are to be provided to protect the piping from damage due to vehicle collision.

6.3.1.6 For ships carrying dangerous chemicals in bulk, the gas supply piping is not to pass through tanks and cargo pump-rooms.

6.3.2 Gas fuel heating

6.3.2.1 The temperature at the gas outlet of the heat exchanger is to be monitored. When the temperature is too low, 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 any) is to be automatically shutdown and the tank master valve is to be shutoff.

6.3.2.2 *The circuit in which the 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;

(4) *The vents of gas heating circuit expansion tank are to lead to the 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.*

Section 4 GAS SUPPLY SYSTEMS INSIDE THE MACHINERY SPACE

6.4.1 Gas supply systems within gas safety machinery spaces

6.4.1.1 Gas supply piping in gas safe machinery spaces is to be double wall piping, which could be designed to be one of the following two forms:

(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; or

(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 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 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. but:

(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 sea-going ships engaged on domestic voyages, double wall piping may be dispensed with to the air inlet pipe of the engine, provided that gas is sucked or injected 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, the design pressure of the duct is to be the greater of the followings for high pressure gas piping systems:

(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 CH4. 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, but the test report is 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 within 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;

(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 function.

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), (16) and (17) . In particular the following is to 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; and

(4) All gas consumers are to have a separate exhaust system.

7.1.3 General requirements

7.1.3.1 *In addition to the requirements of the Relevant Rules, gas engines are to comply with the relevant requirements of Chapter 7, Chapter 12 and ANNEX 3, and are to hold a marine products certificate.*

7.1.3.2 *For gas engines with electronic control systems, the electronic control systems are to comply with the relevant requirements of Annex 4 of the Rules.*

7.1.3.3 *Engine manufacturers are to specify the extent of variations of methane numbers and low heat values appropriate to the gas engine.*

7.1.3.4 *Risk analysis is to be conducted on all possible faults affecting operation safety of gas fuel engine. Required engine monitoring items are to be determined based on the risk analysis results. Risk analysis is to comply with the requirements of Section 5 of this Chapter and the report is to be submitted to CCS.*

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 purge any unburnt fuel mixture 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 cylinders for starting purposes, the starting air pipes are to be provided with flame arresters, which are to be fitted at starting air branch pipe to each cylinder for direct reversing engines, and at starting air manifold for non-reversing engines.*

7.2.1.2 *Where gas fuel is mixed with air before the turbo-charger, the engine air intake is to be located outside the machinery space provided that the engine is arranged in gas safe machinery space. The engine air intake located inside the machinery space may be accepted where the engine is arranged in ESD protected machinery space.*

7.2.1.3 *Where air intakes are located inside the engine room, they are to be situated as far apart as practicable from the gas fuel supply pipe such that the risk of the leakage gas entering the intake is minimized. Air intakes located outside the engine room are to be lead from a non-hazardous area at least 1.5m from the boundaries of any hazardous area.*

7.2.1.4 *Where gas fuel is supplied into the cylinder through the air inlet manifold, an explosion relief valve or other explosion-proof facilities are to be fitted on the air inlet manifold, except documentation demonstrating that the system has sufficient strength to contain the worst-case explosion. Where gas fuel is mixed with air before the turbocharger, an explosion relief valve is to be fitted on the turbocharger or intercooler, except documentation demonstrating that the turbocharger or intercooler has sufficient strength to contain the worst-case explosion.*

7.2.1.5 *The crankcase of gas fuel engines is to be provided with an explosion relief valve of sufficient relief area unless documentation demonstrating that the system has sufficient strength to contain the worst-case explosion. The total flow area of the explosion relief valves fitted on the crankcase is to be calculated according to the total volume of the crankcase, which is not to be less than 115cm2 for each cubic meter of the crankcase volume, and the flow area of each valve is not to be less than 45cm2. The relief valves are to be provided according to the following: For low pressure gas fuel engines, where the cylinder bore is 200mm or above, at least one relief valve is to be fitted at each end of the crankcase, and another relief valve is to be fitted near the middle of the crankcase provided that the number of the cranks is over eight. Where the cylinder bore is more than 250mm, at least one relief valve is to be fitted on each crank. For the compartments of the crankcase with a gross volume of more than 0.6m3, such as gear housing, chain cases or other similar devices for driving the camshaft, an explosion relief valve is to be provided.*

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 does not exceed LEL in any case, the following requirements are to comply with:

(1) The crankcase is to be provided with oil mist detectors or equivalent devices, such as bearing temperature detectors, to monitor the heat points;

(2) Electrical installation and instruments fitted inside 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 vents are to lead to a safe location in the open area, and their ends are to be fitted with flame arresters. The crankcases are to be provided with interfaces or other equivalent devices for inerting to readily maintain

7.2.1.8 The exhaust pipes are to be equipped with relief valves sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned gas in the pipes

7.2.1.9 *The relief valves required in 7.2.1.8 may be dispensed with if documentation demonstrating that the exhaust pipe has sufficient strength to contain the worst-case explosion.*

7.2.1.10 *The exhaust pipe is to be purged to discharge the combustible gas that may be present in the event a gas fuel engine stops during the gas fuel mode.*

7.2.1.11 *Explosion relief valves that require dismantling or replacement prior to continued engine operation are not to be installed on single engine main propulsion installations, unless 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 shutoff of the gas fuel 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 start, normal stop, idle running, low-load operation, high-load operation and overload operation, except documentation demonstrating 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 gas 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 the 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 *The starting sequence is to be such that fuel gas is not admitted to the cylinders until ignition is activated and the engine has reached an engine and application specific minimum rotational speed.*

7.2.3.4 *Unburnt combustible mixture in the exhaust gas pipe is to be purged after a failed start. Restarting is not to be possible before the exhaust gas 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 shut down sequence is to be such that the engine gas supply system closes at idle speed and that the ignition system is kept active until the engine is down to standstill.*

Section 3 MAIN BOILERS 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 providing 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 gaseous 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 Arrangements are to be made that, in case of flame failure of the operating burners, the gas supply piping of the combustion chambers are automatically freed by inerting gas.

7.3.1.9 The automatic fuel changeover system required by 7.3.1.4 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 acc2.3.3 and 6.4.2, 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 for ESD protected machinery spaces, but is in addition to be arranged with full redundancy (2 x 100% capacity fans from different electrical circuits).

7.4.1.5 For other than single fuel gas 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 fuel gas supply is to be shutdown.

7.4.1.7 Each turbine is to be fitted with an automatic shutdown device for high exhaust temperatures.

Section 5 RISK ANALYSIS

7.5.1 Extent of risk analysis

7.5.1.1 *An risk analysis is to at least include:*

(1) *a single failure in a technical system or component of the engine when gas firing;*

(2) *a gas leakage downstream of the gas valve unit;*

(3) *the safety in case of an emergency shutdown or power failure of the engine when gas firing;*

(4) *the effects between the gas supply system and the engine.*

7.5.1.2 *Failures in the systems external to engines (such as fuel storage or fuel gas supply systems) may require action from the engine control and monitoring system in the event of an alarm or fault condition.*

7.5.2 Forms of risk analysis

7.5.2.1 *A risk analysis is to be carried out in accordance with recognized standards*[14].

7.5.2.2 *The required analysis is to be based on the single failure criteria, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failure, i.e. failures of any component directly caused by a single failure of another component, is also to be considered.*

7.5.3 Procedures of risk analysis

7.5.3.1 *The risk analysis process is to include:*

(1) *all possible failures in the concerned equipment and systems which could lead:*

① *to the presence of gas in components or location not designed for such purpose; and/or*

② *ignition, fire or explosion.*

(2) *evaluating the consequences;*

(3) *identifying the failure detection method (if necessary);*

(4) *identifying the corrective measures (if risks cannot be eliminated) :*

① *the system design, such as:*

(a) *redundancies;*

(b) *safety devices, monitoring or alarm provisions which permit restricted operation of the system.*

② *in the system operation, such as:*

(a) *initiation of the redundancy;*

(b) *activation of an alternative mode of operation.*

7.5.3.2 *The results of the risk analysis are to be documented and confirmed by a practical test.*

7.5.4 Equipment and system analysis

7.5.4.1 *The risk analysis required for engines is to cover at least the following aspects*：

(1) *failure of the gas-related systems or components, in particular:*

① *gas piping and its enclosure（where provided）;*

② *cylinder gas supply valves*[15].

(2) *failure of the ignition system (oil fuel pilot injection or sparking plugs）;*

(3) *failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.）;*

(4) *for engines where gas is injected before the turbo-charger, failure of a component likely to result in a source of ignition (hot spots)*；

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[14] Refer to ISO 31010 Risk Management - Principles and Guidelines.

[15] Failures of the gas supply components not located directly on the engine (such as block-and-bleed valves and other components of the GVU) are not to be considered in the analysis.

(5) *failure of the gas combustion or abnormal combustion (misfiring, knocking)*；

(6) *failure of the engine monitoring, control and safety systems*[16]；

(7) *abnormal presence of gas in engines components (e.g. air inlet manifold and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct)*；

(8) *changeover of fuel modes for dual fuel engines.*

[16] Where engines incorporate electronic control systems, the risk analysis is to demonstrate that failure of an electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criterion of the engine.

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).

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 for fire protection purposes.

8.2.1.2 The fire protection of fuel pipes led through ro-ro spaces is to be subject to special consideration by CCS depending on the use and expected pressure in the pipes.

8.2.2 Fuel storage tanks

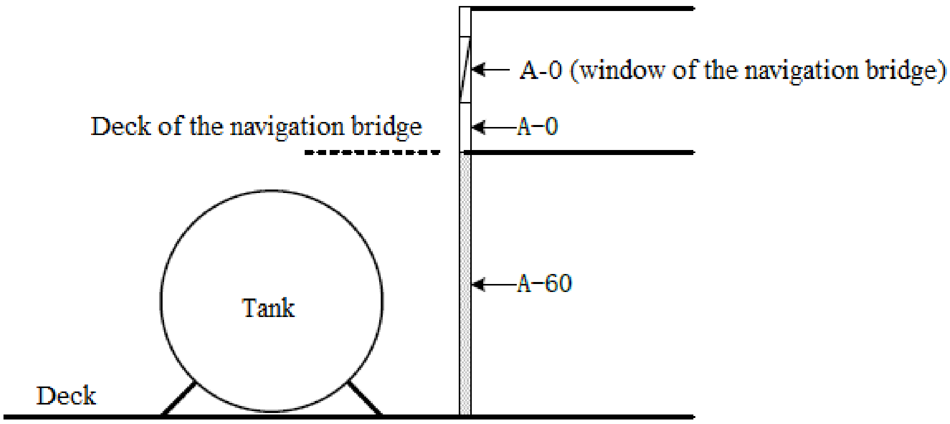
8.2.2.1 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, is to be shielded by A-60 class divisions. These class divisions are to extend up to the underside of the deck of the navigation bridge or up to the true height of the bulkhead, and any boundaries above that, including navigation bridge windows, are to have A-0 class divisions. For the purposes of the stowage and segregation requirements of the IMDG Code, a fuel tank on the open deck is to be considered a class 2.1 package.

8.2.2.2 Isolation is to be provided between the fuel storage hold space and machinery spaces of category A/essential machinery spaces or other space is to be done by a cofferdam of at least 900 mm with insulation of A-60 class. 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. The boundary between fuel storage hold spaces is to be either a cofferdam of at least 900 mm or A-60 class division.

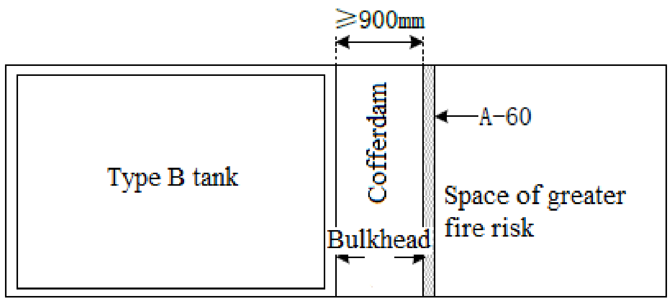
8.2.2.3 *For type C independent tanks, the fuel storage hold space may be considered as a cofferdam, provided that the outer shell of the tank is not to be less than 900 mm away from the bulkhead of the fuel* *storage hold space. When a type C independent tanks is directly located above the machinery spaces 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 done by a cofferdam of at least 900 mm with insulation of A-60 class. For inland waterways ships, if this is impracticable, the distance of 900 mm may be reduced but not less than 500 mm after assessment.*

8.2.2.4 The fuel storage hold space is not to be used for machinery or equipment that may have a fire risk.

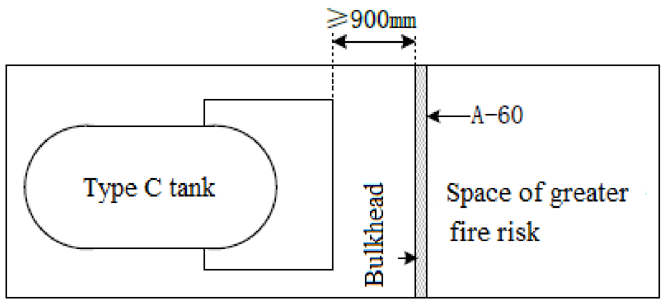
8.2.2.5 *The requirements of 8.2.2.2 and 8.2.2.3 above are shown in Figure 8.2.2.*



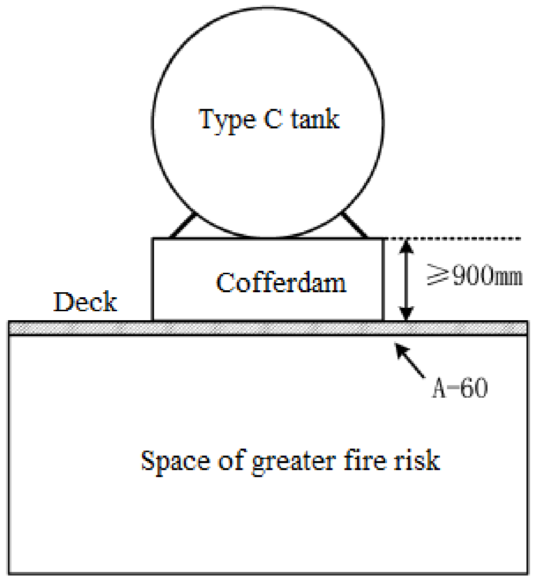
① Tanks located on the open deck



② Tanks located in an enclosed space



③ Tanks (type C in dependent tanks) located in an enclosed space



④ **Tanks located above the space of greater fire risk**

Figure 8.2.2 Fire divisions of fuel storage tanks

8.2.3 Bunkering stations

8.2.3.1 The boundaries of a machinery spaces of category A/essential machinery space, accommodation space, control station and space of greater fire risk facing the bunkering station are to be insulation of A-60 class, but the boundaries of a liquid tank, void, auxiliary machinery space and sanitary of minor fire risk and other similar space may be reduced to A-0 class.

8.2.3.2 *For sea-going ships engaged on domestic voyages, the bunkering station may have insulation reduced to A-0 class where it is located on the weather deck and the bunkering connection is greater than 10 m away from the bulkheads of the spaces mentioned in 8.2.3.1. When the bunkering connection is located at the sunken part of the superstructure and deckhouse, it may be considered as being located on the weather deck, provided that the depth of the sunken part does not exceed 1 m. Details see Figure 8.2.3.*

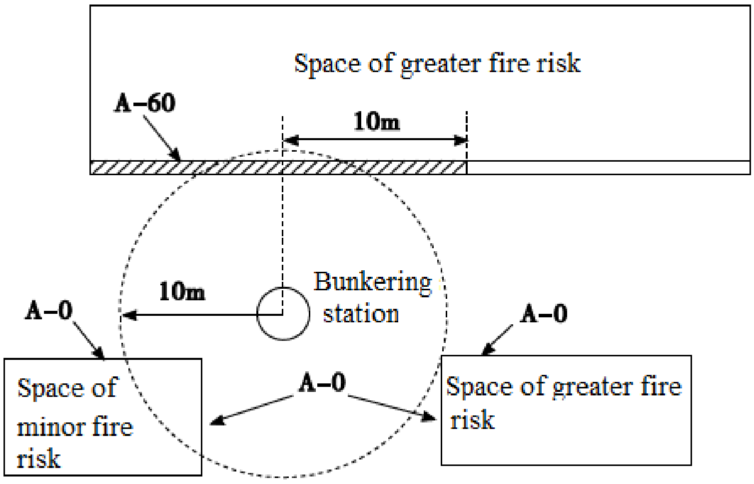


Figure 8.2.3 Fire divisions of bunkering stations
(for sea-going ships engaged on domestic voyages

8.2.4 ESD protected machinery spaces

8.2.4.1 If an ESD protected machinery spaces is separated by a single boundary, the boundary is to be of A-60 class division.

Section 3 FIRE EXTINCTION

8.3.1 General requirements

8.3.1.1 *Fuel preparation rooms, gas compressor rooms and gas pump rooms (if any) are to comply with the fire safety requirements for cargo compressor rooms and cargo pump rooms of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.*

8.3.2 Fire mains

8.3.2.1 *At least two power pumps are to be provided, and the capacity and pressure of each pump are to be sufficient to ensure the simultaneous use of two water jets with a throw 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 Chapter simultaneously.

8.3.2.3 When the fire main passes through the tank area on the open deck, 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 *All fire hose nozzles are to be dual-purpose (water/water spray type) with switches.*

8.3.3 Water spray systems

8.3.3.1 A water spray system is to be installed for cooling and fire prevention 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 metres or more from the boundaries.

8.3.3.3 *For inland waterways ships, the water spray system need not provide coverage for the boundaries mentioned in 8.3.3.2 if they are greater than or equal to 5 m away from the tank.*

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 the largest horizontal projected surfaces and 4 l/min/m2 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 metres, 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 access

8.3.3.9 The nozzles are to be of an approved full bore 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 the open deck, at least two portable dry powder extinguishers of at least 5 kg capacity are to be located near the tank.*

8.3.4.2 *Where the tank is located in an enclosed space or semi-enclosed space, at least one portable dry powder extinguisher of at least 5 kg capacity are to be located near the entrance of the tank.*

8.3.4.3 The bunkering station is to be fitted with a fixed dry powder fire-extinguishing system or large dry chemical wheeled fire extinguisher which is to cover all possible leakage 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.

8.3.4.4 In addition, at least one portable dry powder extinguisher of at least 5 kg capacity are to be located near the bunkering station.

8.3.4.5 *At least one portable dry powder extinguisher of at least 5 kg capacity is to be fitted near the gas engine and the entrance of the machinery space where it is located.*

Section 4 FIRE DETECTION AND FIRE ALARM SYSTEMS

8.3.1 Fire detection

8.4.1.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems 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.

8.4.1.3 If the fire detection system cannot identify each detector, each detector is to be set up to be a single loop.

8.4.2 Alarm and safety actions

8.4.2.1 *On detection of fire mentioned in 8.4.1.1, safety measures specified in Table 12.4.3 of the Rules are to be adopted and ventilation is to be automatically shutoff.*

CHAPTER 9 EXPLOSION PROOF

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), (8), (12) to (14) and (17). In particular the following apply:

The probability of explosions is to be reduced to a minimum by:

(1) reducing number of sources of ignition; and

(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 standard[17]. The electrical equipment fitted within hazardous areas are 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 a recognized standard[18].

9.1.3.3 Electrical equipment fitted in an ESD-protected machinery space is to fulfil 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 are 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

9.2.1.1Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to

[17] Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.

[18] Refer to IEC standard 60092-502: IEC 60092-502:60092 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.

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 2[19]. See also 9.2.1 below. See also 9.2.2 below.

9.2.1.3 Ventilation ducts are to have the same area classification as the ventilated space.

9.2.1.4 *Spaces with entry openings to the adjacent hazardous area may be a non-hazardous area by adopting the measured of 2.3.8.1.*

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 1[20]

This zone includes, but is not limited to:

(1) tank connection spaces, fuel storage hold spaces[21] and interbarrier spaces;

(2) fuel preparation rooms provided with ventilation according to 10.4.1;

(3) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet[22], vent of the crankcase of the gas engine, 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) spaces on the open deck within drip trays for bunker manifold valve and 3 m beyond these, up to a height of 2.4 m above the 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 will require equipment required to operate following loss of differential pressure between the protected space and the

[19] Refer to standards IEC 60079-10-1:2008 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:60092, Electrical Installations in Ships – Tankers – Special Features for tankers.

[20] Instrumentation and electrical apparatus installed within these areas should be of a type suitable for zone 1.

[21] Type C independent tank spaces are in general not to be considered as Zone 1.

[22] 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.

hazardous area to be certified as suitable for zone 1; and

(9) except for type C 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[23]

These include, but are not limited to:

(1) areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1;

(2)Space containing bolted hatch to tank connection space.

Section 3 ELECTRICAL INSTALLATIONS AND CABLES WITHIN THE HAZARDOUS AREA

9.3.1 Selection of electrical apparatus corresponding to hazardous areas

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 II A T2, The following electrical equipment may be accepted in different hazardous zones:*

(1) *Equipment for Zone 0*

a) *certified intrinsically-safe apparatus of category "ia";*

b) s*imple 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 (except in the cases of switches, plugs and sockets, and terminals) the maximum surface temperature of any part of the apparatus. 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 CCS 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) *Equipment for Zone 1*

a) *equipment which may be used in Zone 0;*

b) *certified intrinsically-safe apparatus of category "ib";*

c) *simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction*

[23] Instrumentation and electrical apparatus installed within these areas should be of a type suitable for zone 2.

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;

d) *certified flameproof (type "d"); e) certified pressurized (type "p"); f) certified enhanced safety(type "e"); g) certified encapsulated (type "m"); h) certified sand filled (type "q");*

i) *certified specially (type "s");*

j) *hull fittings containing the terminals or shell-plating penetrations for anodes or electrodes of an impressed current catholic protection system, or transducers such as those for depth sounding or log systems, provided that such fittings are located in gastight enclosed spaces and not be adjacent to the bulkhead of the tank;*

k) *route cables.*

(3) *Equipment for Zone 2*

a) *equipment which may be used in Zone 1;*

b) *equipment of type "n";*

c) *equipment 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 are 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 Selection and installation of cables

9.3.2.1 T*he 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 which they are to be intended to install, taking account of the mechanical, chemical and corrosion factors etc.*

9.3.2.3 *Where cables pass through the deck or bulkhead within a hazardous area, the tightness of the deck or bulkhead is to be maintained.*

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 required for 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）.

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 will be operating 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 alloys or magnesium alloys 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) The radial air gap between the impeller and the casing is to be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 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 gas 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 fitted in the safe area 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 gas-tight 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 plant is normally to be 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: 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 standard[24] 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 standard[25] in the non-hazardous space is to be required.

[24] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.
[25] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

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 *Mobile ventilation plants are to be provided in hazardous spaces where crew do not enter often, such as empty places or similar places. Ventilation is to be provided before entrance into such places with the notice board of ventilation. The explosion-proof degree of a mobile ventilation plant is to be matched with the level of the gas hazardous area and hold a marine products certificate.*

10.1.3.14 *Ventilation fans associated with the hazardous space are to be fitted with substitutes.*

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.*

10.1.3.17 *An audible and visual alarm is to be given at a manned location.*

10.1.3.18 *Suitable means are to be provided to prevent ventilation circuits formed by the pipes where the fan is located and the pipes where other pipes are located in case of failure of a fan or a group of fans.*

10.1.3.19 *For mechanical ventilation systems of the extraction type within hazardous spaces, inlets of each air duct are to be carried out according to the area where combustible gas may be accumulated and are to be generally arranged on the top of the spaces.*

10.1.3.20 *For passenger ships required to meet the requirements for safe return to port, any opening within the safe area*[26] *is not to be located in an gas hazardous area, and the ventilation inlets is to be at least 1.5 m away from the boundary of the 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.

10.2.1.3 The ventilation system is to be of continuous operation in case of gas fuel operation on engine.

10.2.1.4 *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 3 MACHINERY SPACES

[26] Refer to SOLAS regulation II-2/21.

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.

10.3.1.2 *The ventilation system is to be of continuous operation in case of gas fuel operation on engine.*

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 is detected. As an alternative, arrangements whereby 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 standard acceptable to CCS[27].

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 *Starting of pumps and compressors is not to be possible before the ventilation system has run for 10 min.*

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

[27] Refer to IEC 60079-10-1:2008 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres.

any vapour being released during bunkering operations 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.

Section 6 DOUBLE PIPES

10.6.1 General requirements

10.6.1.1 Ducts and 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 applicable to double pipes in the engine-room if fulfilling 6.4.1.1.

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.

10.6.1.3 The ventilation inlet for the double wall piping is always to be located in a 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), (2), (4), (7), (8), (11), (13) and (16) to (18). 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 standard at least equivalent to those acceptable to CCS[28].

11.1.3.2 Electrical equipment or wiring are not to be installed in hazardous areas unless essential for operational purposes or safety enhancement.

11.1.3.3 Electrical installations located in the hazardous area specified in 11.1.3.2 are to be in compliance with a standard at least equivalent to those acceptable to CCS[29] for types, installation and maintenance.

Equipment within a hazardous area is to be assessed and certificated or registered by the authorities approved by the authorities approved by CCS.

11.1.3.4 Failure modes and effects of single failure for electrical generation and distribution systems used for maintaining the tank pressure and hull temperature are to be analysed and documented to be at least equivalent to those acceptable to CCS[30].

11.1.3.5 The lighting system 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 units is to be such as to ensure the safe

[28] Refer to IEC 60092 series standards, as applicable.
[29] Refer to the recommendation published by the International Electro technical Commission, in particular to publication IEC 60092-502:1999.
[30] Refer to IEC 60812.

bonding to the hull of the units themselves.

11.1.3.7 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 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 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 liquefied gas fuel containment systems. Fuel pump motors are to be capable of being isolated from their electrical supply during gas-freeing operations.

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, manoeuvring, 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 the gas engine are to be supplied from two power supply, one of is a main source of electrical power and the other is a storage battery or an uninterruptible power system (UPS).These systems is to be capable of automatically converting to the storage battery or uninterruptible power system (UPS) in the event of failure of the main source of electrical power and be capable of showing by an alarm locally or in the navigation bridge. the period of power supply of the storage battery is not to be less than 30 min. where the ship is supplied only from the storage battery, the systems above are to be supplied from two main sources of electrical power.*

11.1.3.13 *Consideration is to be given to the effects between the ship and the bunkering ship, equipment and shore, and explosion proof electrical equipment are suggested to be located at the ship's sides.*

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 this Code.

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). 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 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 and upon other fault conditions which may develop too fast for manual intervention;

(3) For ESD protected machinery configurations, 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) Safety functions are to be arranged in a dedicated gas safe system, and the system is to be separated from the monitoring/control system which includes electric supply and input and output signals, to avoid a common cause failure that may be occur.

(5) The safety functions are to be arranged in a dedicated gas safety 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;

(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 fuel-gas equipment including bunkering.

12.1.3.2 A bilge well in each tank connection space of an independent liquefied gas storage 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, and the safety system is to be activated at low temperature.

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 relevant requirements for monitoring, control and safety see Table 12.4.2 and Table 12.4.3. Where, Table 12.4.2 is for the monitoring/control system and Table 12.4.3 is for the safety system. Where an alarm is required by both tables, it is to be activated by the separate sensors of the monitoring/control system and the 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, and is to activate the gas safety system.*

12.1.3.6 *The safety system is to send electrical signals and its alarm and protection actions to be taken are not to be dependent on the gas control system.*

Section 2 MONITORING AND CONTROL

12.2.1 Bunkering and fuel storage tanks

12.2.1.1 Level indicators for liquefied gas fuel tanks

(1) Each liquefied gas fuel tank is to be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the liquefied gas fuel tank is operational. The device(s) is(are) to be designed to operate throughout the design pressure range of the liquefied gas 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) Liquefied gas 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 liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices;

.3 *closed devices, which penetrate the liquefied gas fuel tank （only for sea-going ships engaged on domestic voyages and inland waterways ships), and is part of the closed system and is capable of preventing fuel spillage, such as a float-type system, electronic probe, magnetic probe and bubbler tube type indicator. Where the close 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 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 in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the liquefied gas fuel tank from becoming liquid full at the high-high level of the tank. This sensor is to be independent from the liquid level sensor required in 12.2.1.2(1).

(3) The position of the sensors in the liquefied gas 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 liquefied gas fuel tank to the alarm point.

(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.

(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 liquefied gas 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 station 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 liquefied gas fuel tank.

12.2.1.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm is to be provided on the navigation bridge and at a continuously manned central control station 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 is 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 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 visual alarm on the navigation bridge, continuously manned central control station 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 the following 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.

However, each independent tank of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit is to be provided with the device above in the locations specified in (1) and (3) above. If the type C independent tanks is less than 2 m in height, the device above is required only in the location specified in (1) above.

12.2.2 Bunkering

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 and tank level is to be monitored. Remotely controlled valves required by 5.3.1.3 and 8.3.3.8 are to be capable of being operated from this location. Overfill alarm and automatic shutdown is 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 On detection of flammable gas enclosing the bunkering lines, an audible and visual alarm is to be provided at the bunkering control location and the gas bunkering is to be shutoff.

12.2.3 Gas compressors

12.2.3.1 Gas 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 give 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 temperature and circulation of heat mediums of heat exchangers are to be monitored, and a low temperature alarm is to be provided. An alarm is to be given at the point the heat medium stops circulating and simultaneously the LNG transfer pump and related tank master valves are to be shutdown to avoid icing of the heat medium.*

12.2.4.2 *The temperature at the heat exchanger outlet is to be monitored, and a low temperature alarm is to be provided. When the temperature is too low, the shutoff valve on the pipe supplying to the heat exchanger is to be shutoff.*

12.2.5 Gas engines

12.2.5.1 In addition to the diesel 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 CCS Rules for the Construction of Sea-going Ships Engaged on Domestic Voyages or CCS Rules for the Construction of Inland Waterways Steel, as applicable, indicators are to be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

(1) operation of the engine in case of gas-only engines; or

(2) operation and mode of operation of the engine in the 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 on the navigation bridge or in a continuously manned central control station or safety centre.

12.2.6.2 *Run signals of electric motors driving fans are not to be accepted as equivalent.*

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.*

12.2.7 Bilge wells

12.2.7.1 *The bilge wells of tank connection spaces and fuel preparation rooms are to be fitted with liquid level sensors, and all related valves are to be automatically shutdown by the safety system at a low temperature, to isolate the low temperature leakage.*

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) the tank connection spaces;

(2) the spaces between the internal and external pipes of double walled 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 or 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; and

(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 the ventilated duct and have an inner space of not more than 2 m^3; and*

(12) inlet openings of accommodation spaces and machinery spaces which may contain flammable gas after the risk analysis according to 1.1.6.

12.3.1.2 *Two independent gas detectors located close to each other are required in 12.3.1.1 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 and spares are to be provided for timely replacing.*

12.3.1.3 *On detection of a failure of gas detector with the self-examination function are used, it is to be the same as detection of high gas concentration for the gas safety system or gas 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, layout 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 is to 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 standard[31].

12.3.1.8 An audible and visible alarm is to be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system is to be activated at 40% of LEL at two detectors (see footnote 1 in Table 12.4.3).

12.3.1.9 For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The safety system is to be activated at 60% of LEL at two detectors (see footnote 1 in Table 12.4.3).

12.3.1.10 Audible and visible alarms from the gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station.

12.3.1.11 Gas detection required by this Section is to be continuous without delay.

12.3.1.12 *Gas detection equipment fitted in interbarrier spaces and fuel storage hold spaces not for type C independent tanks 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 compartment.*

12.3.1.14 Safety actions are to be provided for the gas engine machinery space and the fuel storage hold space of independent tanks according to Table 12.4.3.

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 valve, the fuel supply is not to be

[31] Refer to IEC 60079-29-1 – Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable detectors.

opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible 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 notto be operated until the leak has been found and dealt with. Instructions to this effect are to be placed in a prominent 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-fuelled 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 is 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 of Table 12.4.2 and Table 12.4.3 involve fuel bunkering, the indication, alarm and safety actions are to be arranged in the bunkering control location and/or other safe locations. The alarms specified in Table 12.4.3 are to be arranged in the navigation bridge or continuously manned control room or onboard safety centre.*

12.4.1.6 *In addition to the actions required in Table 12.4.3 of this Chapter for gas-only systems, the following actions are to provide in case of loss of ventilation of the machinery space:*

(1) *For electrical propulsion systems serving for multiple engine rooms, the other engine is to start. The first engine is to automatically shutdown in the event of 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 where there are at least 40% of the effective propulsion power and normal power supply serving for navigation.*

(3) *For single engine room, the master gas fuel valve and block-and-bleed valves on gas supply pipes are to automatically shutdown in case of loss of ventilation of gas double walled pipes or pressure loss of inert gas, provided that the other gas supply pipe has been ready.*

12.4.1.7 *For passenger ships required to meet the requirements for safe return to port, monitoring of gas supply systems is to be located and carried out in the onboard safety centre*[32].

[32] Refer to SOLAS regulation II-2/23.

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 block-and-bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifold	Remarks
Compressors and heat exchangers					
Low compressor inlet pressure	×				
Low compressor output pressure	×				
High compressor discharge pressure	×				
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) Valves specified 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)]	Automatic shutdown of master gas fuel valve and block-and-bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifold	Remarks
Fuel storage tanks, bunkering stations and bunkering pipes					
High liquid level in the tank	×				
High pressure in the tank	×				
Low pressure in the tank	×				See 12.2.1.5.
High-high level in the tank	×			×	Only alarm not in the bunkering conditions
Low cable level of submerged bump	×				Stop of fuel pump

To be continued

Parameters	Alarm	Automatic shutdown of tank master valve[6)]	Automatic shutdown of master gas fuel valve and block-and-bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifold	Remarks
Detection of gas concentrations above 20% LEL in the enclosed or semi-enclosed bunkering station	×				
Detection of gas concentrations above 20% LEL in the enclosed or semi-enclosed bunkering station by two detectors[1)] *40%LEL*	×			×	
Loss of ventilation of double walled pipe (duct)	×				
Detection of gas concentrations above 20% LEL in the double walled pipe (duct)	×				
Detection of gas concentrations above 20% LEL in the double walled pipe (duct) by two detectors	×			×	
Fuel storage hold spaces, tank connection spaces and interbarrier spaces					
Gas detection in tank connection space at 20% LEL	×				
Gas detection in tank connection space at 20% 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	×	×			
Loss of ventilation of tank connection space;	×				
Failure ventilation of tank connection space;	×	×			Stop of fuel pump at the same time
Gas detection in interbarrier space at 20% LEL	×				See 12.3.1.1 （6）.
Gas detection in tank connection space at 20% LEL	×				See 12.3.1.1 （6）.
Fuel preparation rooms					
Gas detection in fuel preparation room at 20% LEL	×				
Gas detection in fuel preparation room at 40% LEL by two detectors	×	×2）			
Bilge well high level in fuel preparation room	×				

Bilge well low temperature in fuel preparation room	×	×			

To be continued

Parameters	Alarm	Automatic shutdown of tank master valve[6)]	Automatic shutdown of master gas fuel valve and block-and-bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifold	Remarks
Loss of ventilation of fuel preparation room	×				
Failure ventilation of fuel preparation room	×	×			
High temperature of bulkhead shaft gland and bearing	×				See 12.2.3.2.
Gas supply pipes between the fuel storage tank and the machinery space					
Gas detection in double walled pipe between the tank and the machinery space at 20% LEL	×				
Gas detection in double walled pipe between tank and machinery space at 20% LEL by two detectors	×	×2）			
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	×				
Failure ventilation in duct between tank and machinery space containing gas-fuelled engines	×		×2）		
Gas valve unit spaces					
Gas detection in gas valve unit space at 20% LEL by one detector	×				
Gas detection in gas valve unit space at 20% LEL by two detectors	×		×3）		
Failure ventilation in gas valve unit space	×		×3）		
Machinery spaces containing gas 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 specified in 6.2.1.10 and 6.4.1.3
Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	×				If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in duct inside machinery space containing gas-fuelled engines at 60% LEL by two detectors	×		×3）		If double pipe fitted in machinery space

Gas detection above engine inside gas safety machinery space at 20% LEL	×				See 6.4.1.2（2）

To be continued

Parameters	Alarm	Automatic shutdown of tank master valve[6)]	Automatic shutdown of master gas fuel valve and block-and-bleed valve, and opening of automatic venting valve	Automatic shutdown of stop valve of bunkering manifold	Remarks
Gas detection above engine inside gas safety machinery space at 40% LEL by two detectors	×		×7）		See 6.4.1.2（2）
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	×				
Gas detection in ESD protected machinery space containing gas-fuelled engines at 40% LEL by two detectors	×		×		It is also to disconnect non certified safe electrical equipment in machinery space
Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5)]	×				
Failure ventilation in duct inside machinery space containing gas-fuelled engines[5)]	×		×)3		If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	×				
Failure ventilation in ESD protected machinery space containing gas-fuelled engines	×		×		
Miscellaneous					
Abnormal pressure in gas supply line	×				
Failure of working medium controlling valve	×		×4）		Time delayed as found necessary
Automatic shutdown of engine (engine failure)	×		×4）		
Manually activated emergency shutdown of engine	×		×		
Manually shutdown fuel supply	×		×		See 12.4.1.4.
Manually shutdown fuel bunkering	×			×	See 12.2.2.1.
Gas detection in enclosed/semi-enclosed space where gas may accumulate at 20% LEL	×				See 12.3.1.1（6）
Gas detection in air lock at 20% LEL	×				See 12.3.1.1（7）
Gas detection in gas heating circuit expansion tank at 40% LEL	×				See 12.3.1.1（8）
Gas detection in motor room associated with fuel system at 20% LEL	×				See 12.3.1.1（9）

To be continued

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)) then pressure loss of inert gas is to lead to the same actions as given in this table. 6) Valves specified in 6.2.1.1. 7) *Only applicable to dual fuel engines.* 8) *May be a stop valve specially used in case of rapture of the gas supply piping.*

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, inspection and documentation care to the relevant requirements of the Relevant Rules/guidelines, such as CCS Rules for Materials and Welding and CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, or recognized standards.

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 according to Section 3 of this Chapter. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of CCS.

Section 2 GENERAL TESTING REQUIREMENTS

13.2.1 Tensile tests

13.2.1.1 Tensile tests are 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 tests

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 regulations 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 the relevant requirements of CCS Rules for Materials and Welding. The testing and regulations for specimens smaller than 5.0 mm in size are to be in accordance with recognized standards. Minimum average values for sub-sized specimens are to be:

Minimum Average Energy of Charpy V-notch specimens **Table 13.2.2.1**

Charpy V-notch specimen size (mm)	Minimum average energy of three specimens (J)

10×10	KV
10×7.5	5/6KV
10×5	2/3KV

Note: KV——the energy values (J) specified in Table 3.3.1.1(1) to Table 3.3.1.1(4. 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.

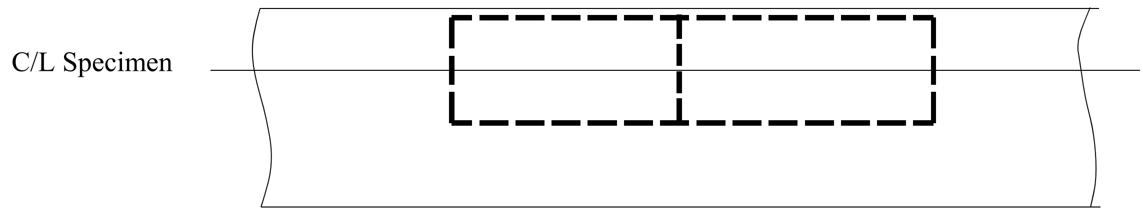


Figure 13.2.2.2 Orientation of base metal test specimen

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.

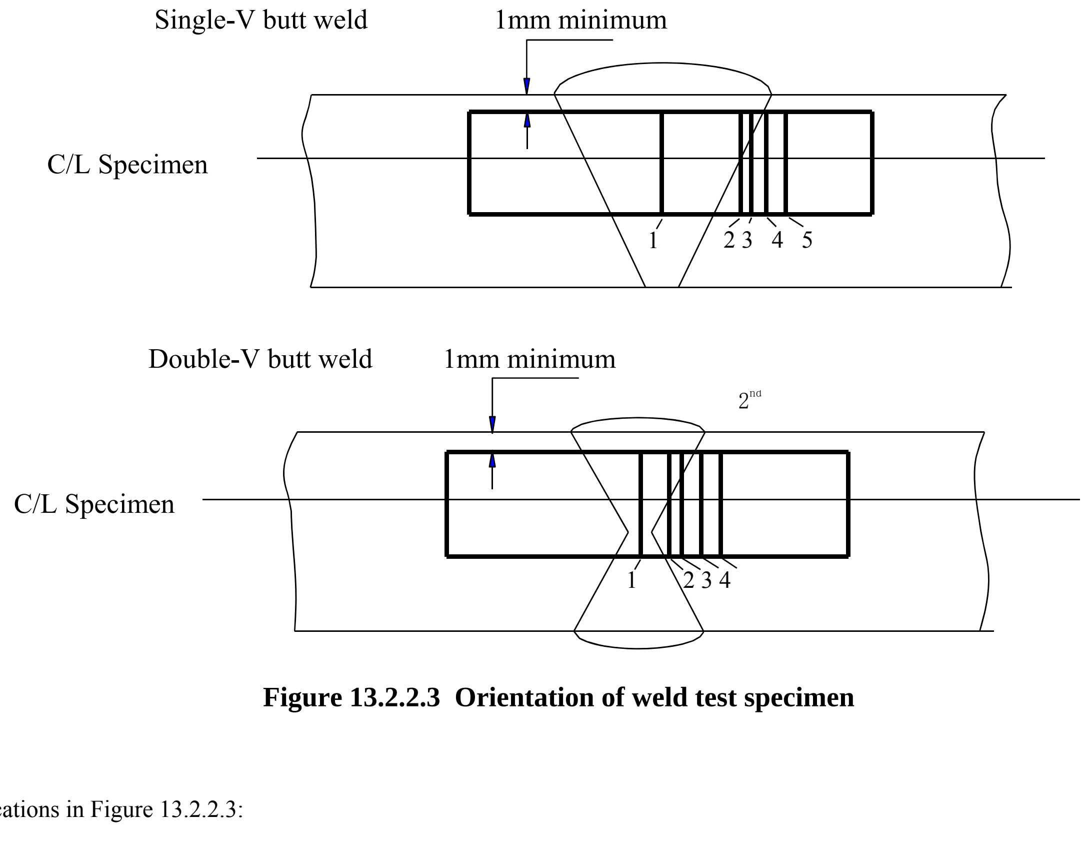


Figure 13.2.2.3 Orientation of weld test specimen

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 heat-affected zone (HAZ), 3 mm from fusion line;

.5 in heat-affected zone (HAZ), 5 mm from fusion line.

13.2.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated regulations, 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 regulations 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 tests

13.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Tensile testing is to be carried out in accordance with 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 THE FUEL CONTAINMENT SYSTEM

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 steels, 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. 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 to be 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 done 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 survey 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 alloys, reference is to be made to 4.2.10.1(4) of the Rules with regard to the regulations 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 or minimum yield stress considered in design of the parent metal.

(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 five times the thickness of the test pieces where its thickness is not more than 12.5 mm; and bended in a diameter six 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 defect 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 regulations for sub-size specimens and single energy values are to be in accordance with 13.2.2 of the Rules. 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 the Rules. 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 Consumables intended for welding of fuel tanks 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 the Rules.

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 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 tests are to be made for each 50 m of weld. 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 the Rules. Tensile tests are to meet regulation 13.3.3.5.

For longitudinal tensile tests, the yield stress of the deposited weld metal is not to be less than the specified minimum yield stress or minimum yield stress considered in design of the parent metal.

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 regulations 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 the relevant requirements of Chapter 7 of CCS Guidelines for Survey of Ship Welding. Where the full penetration butt welds of the tanks (except for membrane tanks) apply Chinese shipping standards (CB) or Japanese Industrial Standards (JIS), the acceptance level is to be Grade I. where they apply the standards of International Organization for Standardization (ISO), the acceptance level for hull structures is to be in accordance with the requirements for important regions.

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:

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 the Rules, 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: 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 Inspection of piping is to be carried out in accordance with the regulations of Chapter 7 of the Rules and CCS Rules for Materials and Welding.

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 REGULATIONS FOR CONSTRUCTION IN METALLIC MATERIALS

13.4.1 General requirements

13.4.1.1 Inspection and non-destructive testing of welds are to be in accordance with regulations in 13.3.5 and 13.3.6 of the Rules. 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 thickness, are to comply with recognized standards. The tolerances are also to be 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 regulations for testing and inspection of secondary barriers are to be approved or accepted by CCS (see also 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 inspection 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.

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 Regulations with respect to inspection of secondary barriers are to be decided by CCS in each case, taking into account the accessibility of the barrier (see also 4.2.3.2).

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, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out in accordance with the requirements of CCS.

13.5.1.8 Heating arrangements, if fitted in accordance with 4.2.11.1(3) and 4.2.11.1(4), 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 as specified in 13.5.2 of this Chapter for type A independent tanks,

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 veis to be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 P_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.

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, regulation in 13.5.4.1 of this Chapter is 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 4.2.16.1② 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. 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 are 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 WELDIGN, 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 steels and to comply with the relevant requirements of CCS Rules for Materials and Welding. CCS may waive the regulations 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 correctly and according to 13.6.3.2 to 13.6.3.5 of this Chapter, the following tests are o 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;

(3) gas supply pipes in ESD protected machinery spaces;

(4) inside diameters of more than 75 mm; or

(5) wall thickness 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 regulation 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, spot radiographic or ultrasonic inspection or other non-destructive tests are to be carried out depending upon service, position and materials by 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 piping component intended to be used at a working temperature below minus 55°C is to be subject to the type tests specified in 13.7.1.2 to 13.7.1.5.

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 be to 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°C, the type testing is to include a fire test to a standard at least equivalent to those acceptable to CCS[33].

13.7.1.6 *Type testing of valves*

(1) *Each size and type of piping component intended to be used at a working temperature below minus 55°C is to be subject to the design evaluation and type tests for approval. The Surveyor is to be present during type testing, and all valves are to be subjected to the minimum design temperature or lower and a pressure not lower than the maximum expected design pressure. The type testing is to include the hydraulic test at 1.5 times the design pressure for the valve body, including low temperature testing for valve operation or set pressure of safety valve and leakage testing.*

In addition, leakage testing at 1.1 times the design pressure is to be carried out for the valve seat and rod.

(2) *The type testing is not required for valves intended to be used at a working temperature above minus 55°C.*

13.7.1.7 *Product testing of valves*

(1) T*he Surveyor is to be present during testing of all valves in the manufacturer. For all valves, the valve body is to be subjected to a hydraulic test at 1.5 times the design pressure; for valves other than safety valves, leakage testing at 1.1 times the design pressure is to be carried out for the valve seat and rod.*

In addition, each size and type of valves (except for safety valves) intended to be used at a working temperature below minus 55°C is to be subject to a low temperature test to 10% of the products, including valve operation and leakage. The test for 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 test, the survey for certification of valve may be carried out as follows:*

① *Valves intended to be used at a working temperature below minus 55°C are to be subjected to a prototype test in accordance with 13.7.1.6 of this Chapter;*

② *The manufacturer is to have an approved quality system, which has been assessed and certificated and regularly reviewed;*

③ *The quality control program is to include: For all valves, the valve body is to be subjected to a hydraulic test at 1.5 times the design pressure; for valves other than safety valves, leakage testing at 1.1 times the design pressure is to be carried out for the valve seat and rod. The test for the set pressure of safety valve is to be carried out at the ambient temperature. The manufacturer is to hold the test recorded; and*

④ *In addition, each size and type of valves (except for safety valves) intended to be used at a working*

[33] Such as ISO 19921:22218, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods, GB/T22219/ISO 19922 ISO 22219, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

temperature below minus 55°C is to be subject to a low temperature test to 10% of the products, including valve operation and leakage.

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) 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 five times the design pressure without bursting. The duration of the test is not to be less than five 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 (ship deformation, ship accelerations and pipe vibrations) 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.

13.7.2.6 *Where complete documents can be provided to verify that the expansion joints are suitable for the expected working conditions, the prototype testing specified in 13.7.2.2 to 13.7.2.5 of this Chapter may be dispensed with. Where the maximum internal pressure exceeds 0.1 MPa, the above documents are to include sufficient testing information, to verify the reasonability of the design method considered, in particular the correlation between the calculation and the testing results.*

13.7.3 System testing regulations

13.7.3.1 The regulations for testing in this Section apply to fuel piping inside and outside the fuel tanks. However, relaxation from these regulations 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 strength 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 test pressure of outer pipes or ventilated ducts is not to be less than 1.5 times the maximum pressure in general, and the maximum pressure may be taken as the design pressure (see 6.4.1.3 of the Rules), or may be calculated under the most unfavourable condition in case of rupture of the pipes. 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. Where the outer pipes or ventilated ducts contain high pressure pipes, they are to be subjected to pressure testing at a pressure of at least 1 MPa.

13.7.3.4 After assembly on board, the fuel piping system is to be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

13.7.3.5 *After assembly on board, the tank connection space and the outer pipe or ventilated duct of double walled pipe are to be subjected to a leak test using air, or other suitable medium to a pressure not less than 0.02MPa in general, unless otherwise required for the leak 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 is 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) (i.e. time from shutdown signal initiation to complete valve closure) is not to be greater than:

$$\frac{3600U}{BR} \quad \text{(second)}$$

where, U---ullage volume at operating signal level, in m^3;

BR---maximum bunkering rate agreed between ship and shore facility (m3/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 OPERATIONS

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 gas or low-flashpoint fuels minimize the risk to personnel, the ship and the environment and that are consistent with practices for a conventional oil fuelled ship whilst taking into account the nature of the liquid or gaseous fuel.

14.1.2 Functional requirements

14.1.2.1 This Chapter is related to functional requirements in 1.1.3.2. In particular the following is to 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 suitably 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 OPERATIONS

14.2.1 General requirements

14.2.1.1 Operations related to natural gas may refer to the relevant requirements of CCS Guidelines for LNG Fuel Bunkering Operation.

14.2.2 Maintenances

14.2.2.1 Maintenances and repair procedures are to include considerations with respect to the tank location and adjacent spaces (see chapter 5).

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.

14.2.2.3 Maintenance and repair procedures 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 standard[34].

[34] Refer to IEC 60079 17:2007 Explosive atmospheres – part 17: Electrical installations inspection and maintenance.

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;

(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 operations 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 manual

14.2.4.1 The fuel handling manual required by 14.1.2.1(2) 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) specific fuel properties and special equipment needed for the safe handling of the particular fuel;

(7) fixed and portable gas detection operation and maintenance of 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.

14.2.4.2 A fuel system schematic/piping and instrumentation diagram (P&ID) are to be reproduced and permanently mounted 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 operations, 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 is to have direct and immediate communication with all personnel involved in the bunkering operation.

14.2.6.4 The ship shore link (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[35].

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[36].

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 is to be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations are to wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer is to be cause to stop operations 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

[35] Refer to ISO 28460, ship-shore interface and port operations.

[36] Refer to API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals.

an equivalent level of safety as integrated fuel 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.

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[37].

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 gas atmospheres, 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.

[37] Refer to the Revised recommendations for entering enclosed spaces aboard ships (A.1050(27)).

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 a separate offshore floating body, where fuel tanks, heat exchangers, control systems, valves and pipes etc. are installed (hereinafter referred to as the separate 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 types of ships of CCS Rules for the Construction of Inland Waterways Steel Ships.*

15.1.1.3 *The separate 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 a 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 a working ship and a floating body in accordance with the relevant requirements of CCS Rules for the Construction of Inland Waterways Steel Ships, and mooring equipment are to be provided based on the sum of both the equipment numbers. The mooring equipment is 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 fibre material.*

15.2.1.2 *Anchors and chains are to be provided based on the equipment numbers of the working ship and 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 *Steel fenders are to be fitted along the berthing side of the floating body, and the fenders are to be insert plates for strengthening or other equivalent means. The fenders are to be continuously arranged along the deck at side, and their surfaces are to be provided with rubber gaskets or equivalent materials to prevent sparks* *due to the ship's friction. The fenders are to insulated to the working ship.*

15.2.1.4 *An access dedicated for personnel passage is to be fitted between the floating body and the working ship, which is to be at least 850 mm in width, and life-saving appliances are to be provided according to the maximum number of operating personnel on the floating body. Non-operating personnel are 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 on them 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 the floating body to effectively extinguish a fire on the floating body. Carriage requirements for the fire-extinguishing appliances are to be not inferior to that in CCS Rules for Liquefied Natural Gas Bunkering Ships.*

15.2.1.7 *Power distribution systems, main sources of electrical power and lighting of the floating body are to be equipped according to the relevant requirements of 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 comply with the relevant requirements of CCS Rules for Liquefied Natural Gas Bunkering Ships.*

Section 3 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 finite element analysis is required to assess the strength of the connection of the tank seat to the hull structure of the floating body. When finite element analysis is carried out, structural models, boundary conditions and loading conditions considered are to comply with the relevant requirements of 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 the open weather deck, the distance from them to the shell plating of the floating body is to comply with the relevant requirements of the Rules, and warning signs are to be observably provided on the floating body.*

15.3.1.3 *A tank connection space is to be fitted to enclose the tank connections, flanges and valves etc.*

15.3.1.4 *Means 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 *The floating body is to be connected to the working ship by hoses, and the hoses are to comply with the relevant requirements of 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 capable of effective control on the working ship, and the tank master gas valve of the floating body is to be capable of automatic shutdown after disconnecting the ship.*

15.3.1.7 *The connecting hoses of gas supply lines are to be provided with breakaway couplings complying* *with the relevant requirements of CCS Rules for Liquefied Natural Gas Bunkering Pontoons, and it is to ensure that the breakaway couplings 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 tanks and gas supply lines are to refer to the relevant requirements of the Rules, and to be capable of displaying and operating both on the floating body and the working ship.*

15.3.1.10 *Where fuel tanks are located on the weather deck of the floating body, boundaries of accommodation spaces, service spaces, cargo spaces, machinery spaces and control stations on the working ship facing fuel tanks, are 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.*

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 *Risk assessment may be a quantitative, semi-quantitative or quantitative approach, and the approached adopted are to be approved by CCS.*

Section 2 RISK ASSESSMENT ELEMENTS

2.1 Steps of risk assessment

2.1.1 *The risk assessment is to include the following steps at least:*

(1) *preparation;*

(2) *collection of data;*

(3) *hazard identification;*

(4) *definitions of leakage scenarios;*

(5) *failure frequency analysis;*

(6) *impact analysis*

(7) *risk calculation;*

(8) *risk assessment;*

(9) *risk reducing measures.*

2.2 Leakage scenarios

2.2.1 *Hazard identification is to be carried out by 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).*

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.*

2.3 Failure frequency analysis

2.3.1 *The following data sources may be used for failure frequency analysis:*

(1) *failure database applied to the LNG industry;*

(2) *historical statistics of enterprises;*

(3) *failure probability models based on reliability;*

(4) *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 de carried out 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 construction features in hazard evaluation, including all factors which will 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. 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, including at least the following categories of hazards and extents of damage in general:*

(1) *intensity of thermal radiation from a fire;*

(2) *concentration of vapour cloud diffusion;*

(3) *shock wave pressure from explosion.*

2.4.2 *The acceptance criteria of thermal flux and thermal dose of thermal radiation of pool fire are to comply with the provisions in Table 1.*

Table 1 Acceptance Criteria of Thermal Radiation of Pool Fire

	Maximum intensity of thermal radiation (kW/m^2)	*Maximum thermal dose of thermal radiation $[kW/m^2]^{4/3}t$*	*Remarks*
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	*Not applicable*	*Loss of strength (significantly decreased loading capacity)of steel structures exposure to a fire during sustained burning*

2.4.3 *The acceptance criteria of volumetric concentration of vapour cloud diffusion are to comply with the provisions in Table 2.*

Table 2 Acceptance Criteria of Concentration of Vapour Cloud Diffusion

Vapour cloud diffusion	*Volumetric concentration*	*Remarks*
	2.5%	*50% of lower flammable limit of methane*

2.4.4 *The acceptance criteria of shock wave pressure from explosion are to comply with the provisions in Table 3.*

Table 3 Acceptance Criteria of Shock Wave Pressure from Explosion

	Overpressure corresponding to damage (N/m²)		*Categories of overpressure damage*
	Lower limit	*Upper limit*	
Explosion	*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

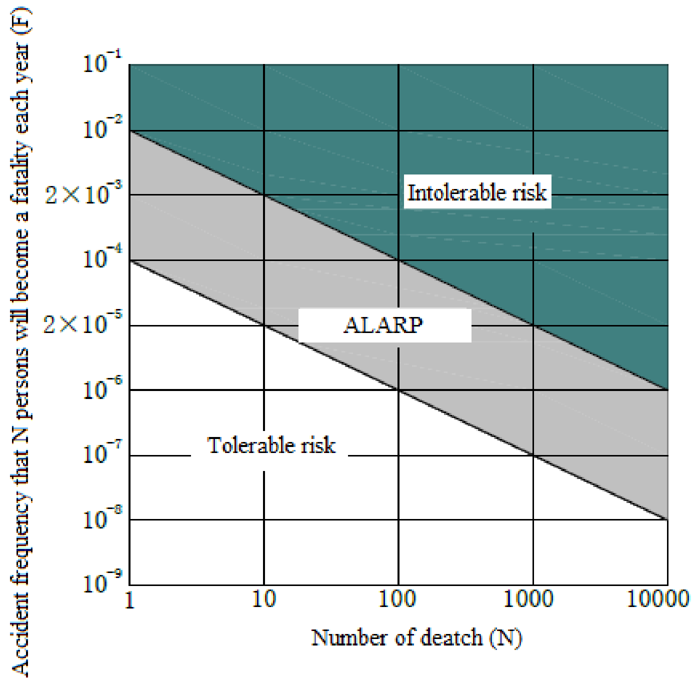
3.1 Definitions

3.1.1 *An individual risk is a probability that an individual is exposed to hazards during a defined period of time, in generally means the probability that an individual will become a fatality each year. The acceptance criteria of individual risk are to comply with the provisions in Table 4.*

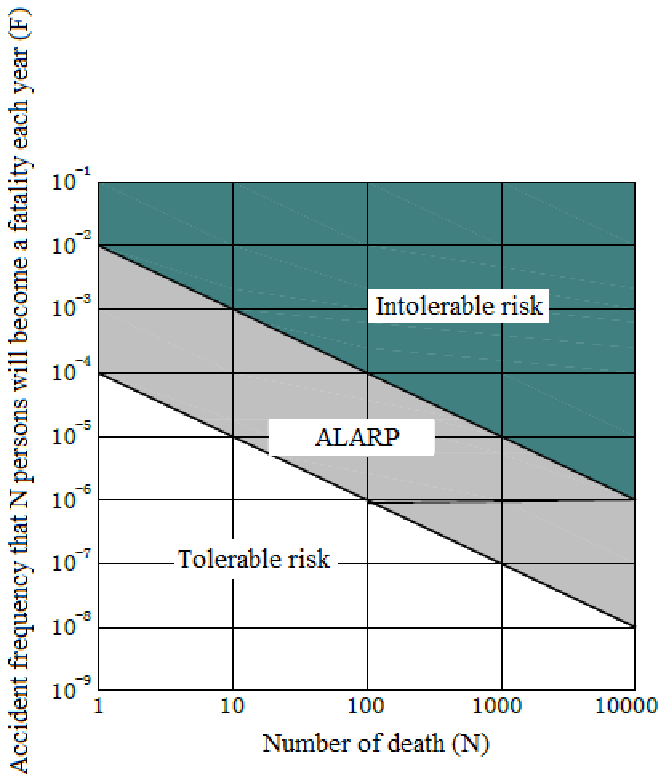
3.1.2 *A social risk is a probability that a group of persons (including employees and the public) is exposed to hazards during a defined period of time, in generally means the accident accumulation frequency that greater than or equal to N persons will become a fatality each year, which is shown in a curve of accumulation frequency and number of death (a F-N curve). The acceptance criteria of social risk are to comply with the provisions in Figure 3.1.2.*

Table 4 Acceptance Criteria of Individual Risk (IR)

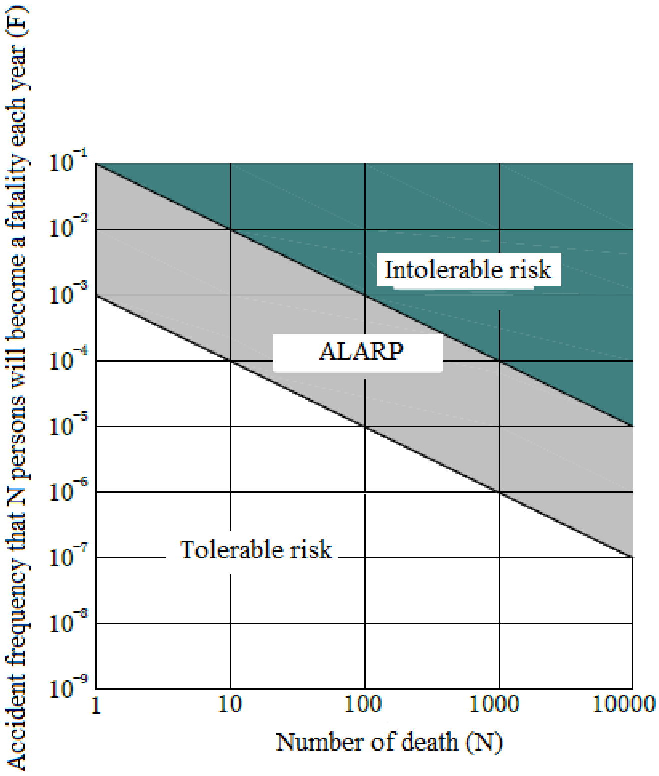
	Value-at-risk (frequency of death/ship/year)	
	Existing ship	*New ship*
Maximum risk acceptable to crew	*1.0E-3*	*1.0E-4*
Maximum risk acceptable to passengers on board or persons on shore	*1.0E-4*	*1.0E-5*
Widely accepted risk	*1.0E-6*	*1.0E-6*



a) Acceptance criteria of social risk (SR) of oil tankers and chemical carriers



b) Acceptance criteria of social risk (SR) of bulk carriers, container carriers and ro-ro ships



c) Acceptance criteria of social risk (SR) of passenger ships

Figure 3.1.2 Acceptance criteria of social risk (SR)

Section 4 RISK REDUCING MEASURES

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 tolerate.*

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.*

ANNEX 2 STANDARDS 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 in accordance with 4.2.17 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. 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 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, 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 the Rules are to be complied with as applicable depending on 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:

$$L_d \le R_d$$

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;

F_k --- the characteristic load as specified in 4.2.7 to 4.2.9 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--- denotes the 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 covered by Chapter 3 of this 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, defined as $\gamma_R = \gamma_m \cdot \gamma_s$;

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, 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 class	Definition
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 in accordance with 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 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	Functional 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 $\gamma_C = 1.2$.This value may be reduced if it is justified through risk analysis and subject to the approval 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 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:

$\gamma_m = 1.1$, when the characteristic mechanical properties specified by CCS typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or

$\gamma_m = 1.0$, 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 paragraph 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 the Rules. R_m and R_e are defined in 4.2.10.1 (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:

$$\sigma_m \le f$$

$$\sigma_L \le 1.5f$$

$$\sigma_b \le 1.5F$$

$$\sigma_L + \sigma_b \le 1.5F$$

$$\sigma_m + \sigma_b \le 1.5F$$

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

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

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;

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

The stresses σ_m, σ_L, σ_b and σ_g are defined in 4.2.14.7 of the Rules.

Guidance note:
The stress summation described above is to be carried out by summing up each stress component $(\sigma_x, \sigma_y, \tau_{xy})$, and subsequently the equivalent stress is to be calculated based on the resulting stress components as shown in the example 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:

$$\sigma_{ms} + \sigma_{bp} \le 1.25F \qquad \text{(see notes 1, 2)}$$

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \le 1.25F \qquad \text{(see note 2)}$$

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \le 3.0F$$

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 the structure, and the methodology used for calculation of stresses.

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 4.2.14.7 of the Rules.

Guidance note:
The stress summation described above is to be carried out by summing up each stress component $(\sigma_x, \sigma_y, \tau_{xy})$, and subsequently the equivalent stress is to be calculated based on the resulting stress components as shown in the example below.

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 paragraph 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 illustrated in Figure 4.3.3.

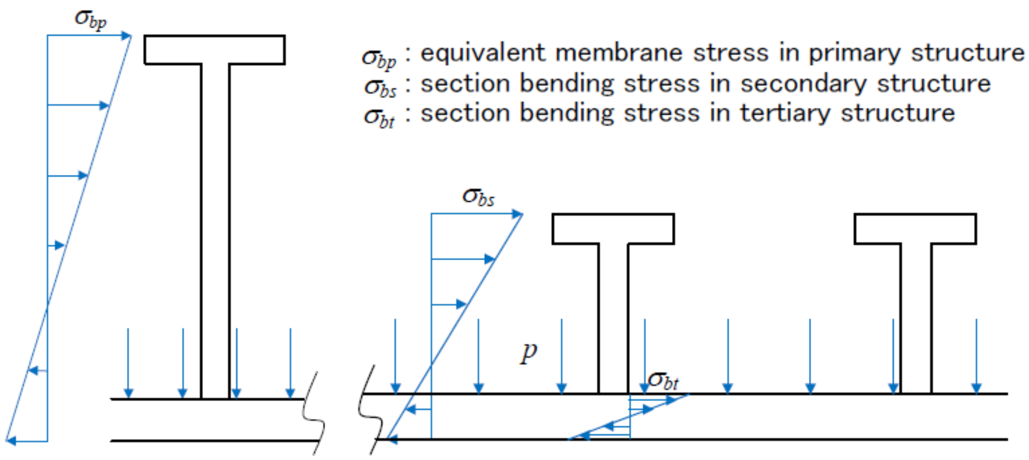


Figure 4.3.3 Definition of the three categories of section stress

(Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.3.4 The same factors γ_C, γ_m and 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 Fatigue design condition as described in 4.2.10.2 is to be complied with as applicable depending on the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under 4.2.17 of the Rules and this Annex.

5.1.2 The load factors for FLS are 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 as described in 4.2.10.2 (2) to 4.2.10.2 (5). The calculated cumulative fatigue damage ratio for the fuel containment systems is to be less than or equal to the values given in Table 5.1.4

Maximum Allowable Cumulative Fatigue Damage Ratio **Table 5.1.4**

	Consequence class		
	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 the Rules, depending on the detectability of the defect or crack, etc.

5.1.5 Lower values may be fixed by CCS.

5.1.6 Crack propagation analysis is to be calculated as described in 4.2.10.2 (7) to 4.2.10.2 (14) of the Rules. The analysis is to be carried out in accordance with methods laid down in a standard recognized by

CCS.

Section 6 ACCIDENT LIMIT STATES

6.1 General requirements

6.1.1 Fatigue design condition as described in 4.2.10.3 of the Rules is to be complied with 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 the Rules need not be combined with each other or with environmental loads, as defined in 4.2.7.4 of the Rules.

6.1.5 Resistance factor γR is in general to be taken as 1.0.

6.1.6 Consequence class factors γ_C are in general 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 are 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 Additional relevant accident scenarios are to be determined based on a 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.

ANNEX 3 TECHNICAL REQUIREMENTS FOR TESTING OF GAS ENGINES

Section 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 *This Annex is applicable to main propulsion gas fuel engine, gas fuel engine for driving generators and important auxiliary equipment.*

1.1.2 *In addition to the relevant provisions of Chapter 9 of PART THREE of CCS Rules for Classification of Sea-going Steel Ships, type testing, works trials and shipboard trials of gas fuel engines are to comply with the requirements of this Annex.*

1.1.3 *Every new engine type of non-mass produced or mass produced intended for the installation on board, one engine is to be presented for type testing as required in section 2 of this Annex. Omission or simplification of the type test may be considered for mass produced gas fuel engine after this kind of type test having been finished, but is to be agreed by the Surveyor.*

1.1.4 *During type testing and works trials, measures are to be adopted to verify the gas tightness of gas pipes of the engine before the engine starts.*

Section 2 TYPE TESTING

2.1 Types of engine

2.1.1 *All of the following items being completely consistent are to be considered as the same type of gas fuel engine:*

(1) *the working cycle (four-stroke, two-stroke);*

(2) *the bore and stroke;*

(3) *gas inlet method (directly into the cylinder, into the air inlet manifold through mixed with air before or after the turbo-charger, into the cylinder air inlet channel port or scavenge space);*

(4) *main and pilot fuel oil (if applicable) injection operation for dual fuel engines (direct or indirect injection);*

(5) *gas inlet valve operation for gas directly entering cylinder or channel port (cam driven or electronic control);*

(6) *gas inlet valve operation for gas into the air inlet manifold, and gas valve operation from air inlet manifold to cylinder (cam driven or electronic control);*

(7) *ignition systems (ignited by pilot diesel, spark plugs or glow plugs or gas self-ignition);*

(8) *categories of fuel (liquid, dual-fuel, gaseous);*

(9) *methods of pressure charging (pulsating system, constant pressure system);*

(10) *charging air cooling systems (with or without intercooler);*

(11) *cylinder arrangement (in-line, vee);*

(12) *rated power per cylinder, rated speed and mean effective pressure.*

2.2 Test procedures

2.2.1 *Stage A—Internal testing*

Internal testing includes development tests and functional tests, and the measured parameters and records of testing hours are to be collected during the testing. The testing results complying with the requirements of CCS or the Designer are to be submitted to CCS before starting stage B.

2.2.2 *Stage B—Official testing*

The Surveyor is to be present during official testing.

2.2.3 *Stage C—Component inspection*

This is the overhaul inspection of the engine component as required by the Surveyor.

2.2.4 *The effects of methane numbers and lower heat value of gas need not be verified in the type testing, however, this verification is to be carried out via internal tests or calculation by the designer of engine, and they are to be recorded in the type testing report.*

2.3 Measurements and records

2.3.1 *In addition to those specified in Annex 5, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, the following parameters are to be measured and recorded:*

(1) *mean effective pressure per cylinder;*

(2) *air charging pressure and temperature;*

(3) *gas pressure and temperature;*

(4) *parameters showing fuel oil or gas consumption or other equivalent parameters.*

Additional parameters related to design assessment may need to be measured and recorded.

2.4 Stage A—Internal testing

2.4.1 *In addition to the relevant provisions of Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, internal tests are to comply with the requirements of this Section.*

2.4.2 *At least the following tests are to be carried out:*

(1) *Dual fuel engines are to be subjected to the relevant tests specified in Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships in gas fuel operation and oil fuel operation respectively;*

(2) *For dual fuel engines having an adjustable gas-oil mixing ratio, loading testing is to be carried out at different ratios within a permissible range.*

(3) *For dual fuel engines, switch over between gas and oil fuel modes are to be tested within certain power leve*[38]*; the effect of gas methane numbers and low heat values is to be subjected testing.*

2.5 Stage B—Official testing

[38] Dual fuel engines are to be capable of changing over from gas fuel operation to oil fuel operation in any loading condition and from oil fuel operation to gas fuel operation within a certain power range, and capable of maintaining a stable speed and output power.

2.5.1 *In addition to the relevant provisions of Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, official testing is to comply with the requirements of this Section.*

2.5.2 *Dual fuel engines are to be subjected to loading tests and functional tests (including overspeed tests) in the oil mode and gas mode as applicable by manufacturers.*

2.5.3 *For dual fuel engines having an adjustable gas-oil mixing ratio, loading testing is to be carried out at different ratios within a permissible range.*

2.5.4 Load points

L*oad point are to comply with the relevant provisions of Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, official testing is to comply with the requirements.*

2.5.5 Functional tests

In addition to the relevant provisions of Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, functional tests are to comply with the following requirements:

(1) *Engines for propulsion*

① *the lower most steady speed test in oil fuel operation;*

② *testing for switching over between gas and oil fuel modes;*

③ *functional tests for ventilated double walled pipes ;*

④ *gas leakage simulation tests for supply valves of cylinders.*

(2) *Engines to drive generator*

① *The capability to take sudden add and loss of load to be tested, the maximum load steps are to be declared and demonstrated. Dual fuel engines automatic switchover to oil fuel during the test is acceptable.*

② *For gas only engines or intake pre-mixing engines, the effects of low heat values, methane numbers and environmental conditions to the results of dynamic response experiment are to be determined in theory, and indicated in the test report. The margin for load transient response is to be determined.*

2.5.6 Integration tests

Gas fuel engines are to be subjected to integration tests to verify that the response of the complete mechanical, hydraulic and electronic systems is as predicted for all intended operational modes. The scope of these tests is to be determined according to the requirements for risk analysis of Section 5, Chapter 7 of the Rules and approved by CCS, and at least the following fault events are to be covered in the tests:

① *failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;*

② *failure of gas supply valve of one cylinder;*

③ *failure of the combustion (misfiring, detonation, exhaust temperature deviation high etc.);*

④ *abnormal gas pressure;*

⑤ *abnormal gas temperature.*

2.6 Stage C—Component inspection

2.6.1 *In addition to those specified in Annex 4, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, the following components are to be inspected after completion of testing:*

(1) *gas supply valves, including pre-chambers, as applicable;*

(2) *squib-initiated igniters, applicable to gas only engines;*

(3) *pilot fuel injection valves, applicable to dual fuel engines.*

Section 3 WORKS TESTING

3.1 General requirements

3.1.1 *Before any official testing the engines have to be run-in as prescribed by the engine manufacturer. Test bed facilities and testing conditions are to comply with relevant provisions.*

3.1.2 *The scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.*

3.1.3 *Dual fuel engines are to be subjected works testing in both oil and gas modes as found applicable.*

3.2 Measurements and records

3.2.1 *In addition to those specified in Annex 6, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, the following parameters are to be recorded:*

(1) *air temperature, air pressure and humidity;*

(2) *power and speed;*

(3) *maximum combustion pressure, applicable to engines having a cylinder head capable of measuring this pressure;*

(4) *exhaust temperature before turbine and each cylinder exhaust temperature;*

(5) *inlet temperature;*

(6) *inlet pressure;*

(7) *turbo-charger speed;*

(8) *parameters showing fuel oil or gas consumption or other equivalent parameters;*

(9) *gas pressure and temperature.*

3.3 Scope of testing

3.3.1 *In addition to those specified in Annex 6, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, at least the following tests are to be carried out:*

(1) *testing for switching over between gas and oil fuel modes of dual fuel engines;*

(2) *functional tests for ventilated double walled pipes.*

3.4 Integration tests

3.4.1 *Gas fuel engines are to be subjected to integration tests to verify that the response of the complete mechanical, hydraulic and electronic systems is as predicted for all intended operational modes. The scope of these tests is to be determined according to the requirements for risk analysis of Section 5, Chapter 7 of the Rules and approved by CCS, and at least the following test items are to be covered:*

(1) *failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;*

(2) *failure of gas supply valve of one cylinder;*

(3) *failure of the combustion (misfiring, detonation, exhaust temperature deviation high etc.);*

(4) *abnormal gas pressure;*

(5) *abnormal gas temperature.*

Section 4 TESTING ON BOARD

4.1 General requirements

4.1.1 *Dual fuel engines are to be subjected on board testing in oil and gas modes respectively as found applicable.*

4.2 Scope of testing

4.2.1 *In addition to those specified in Annex 6, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, the following tests are to be carried out:*

(1) *testing for switching over between gas and oil fuel modes of dual fuel engines;*

(2) *functional tests for ventilated double walled pipes ;*

(3) *testing of monitoring, alarm and safety systems.*

ANNEX 4 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 the Rules.*

Section 2 TECHNICAL REQUIREMENTS FOR TESTING OF GAS ENGINES WITH ELECTRONIC CONTROL SYSTEMS

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 M*onitoring and control function of electronic control system of gas engine are to comply with the relevant requirements in Chapter 10 and Chapter 11 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 mile 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 clauses 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 control system*	*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 above 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 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 installation positions on the gas 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 Approval Test of*

Electric and Electronic Products, type testing of electronic control systems is to comply with the requirements of this Section.

(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 Annex 3.*

(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 sensor*[39]*;*

③ *availability of back-up control module in case of a failure of one control module*[39]*;*

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 module*[39]*;*

⑤ *functions of back-up sensor in case of a failure of one crankshaft position sensor*[39]*;*

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 of Annex 3 combined with gas engine, an ECU is to be subjected to the following testing, as applicable:*

① *verification of data exchanging function with the navigation control system, monitoring system and*

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[39] 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.

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 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 7 of CCS Rules for Classification Sea-going Steel Ships or PART 4 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 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 of 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 stable and normal operational performance for a long time. The measuring range and frequency characteristic (if applicable) of sensors are 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, readily observation and easy operation and maintenance.*

3.3.5 *Instruments are not to be located in a position where without strong electromagnetic interference, high temperature or rapid temperature changes.*

3.3.6 *There is to be room for extension of the connecting pipes and lines of pneumatic and hydraulic actuators, not impede the action of the actuators.*

3.4 Type tests

3.4.1 *The types of gas control systems and gas safety systems are to comply with the relevant requirements of CCS Guidelines for Type Approval Test Approval Test of Electric and Electronic Products.*

3.4.2 *The validity 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 validity 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 testing of 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.*