Proposal for Regulations of dd. month 2016 on ships using fuel with a flashpoint below 60°C

Legal basis: Laid down by the Norwegian Maritime Authority on xx xx 2016 under the Act of 16 February 2007 No. 9 relating to ship safety and security (Ship Safety and Security Act) sections 2, 6, 9, 11, 21, 28a, 29, 30 and 45, cf. Formal Delegation of 16 February 2007 No. 171 and Formal Delegation of 31 May 2008 No. 590.

EEA references: The EFTA Surveillance Authority (ESA) has been notified of the Regulations pursuant to the requirements of Act of 17 December 2004 No. 101 on European notification of technical rules (EEA Hearing Act) and the EEA Agreement Annex II Chapter XIX point 1 (Directive 98/34/EC as amended by Directive 98/48/EC).

Part A

Chapter 1 Scope of application and general provisions

Section 1 *Scope of application*

The Regulations apply to Norwegian ships and vessels using fuel with a flashpoint below 60°C, when such ships and vessels are required to have:

a) vessel instructions
b) trading certificate
c) Passenger Certificate
d) Passenger Ship Safety Certificate (EU) Class B, C and D
e) High-Speed Craft Safety Certificate
f) Passenger Ship Safety Certificate (EU) Class A
g) Cargo Ship Safety Construction Certificate
h) Passenger Ship Safety Certificate.

The Regulations do not apply to cargo ships which are constructed or adapted and used for the carriage in bulk of the liquid products listed in chapter 19 of the IGC Code and which use the cargo as fuel.

Vessel means fishing vessel or high-speed craft.

Section 2 *Technical and operational requirements*

Ships and vessels shall satisfy a recognised classification society's rules for ships using fuel with a flashpoint below 60°C.

IMO Res.MSC.391(95) "International code of safety for ships using gases or other low-flashpoint fuels" (Appendix 1) applies as regulation for ships or vessels required to hold a certificate as referred to in section 1 first paragraph (a) to (e) and:

a) for which the building contract is placed on or after 1 January 2017;
b) in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 July 2017;
c) which are delivered on or after 1 January 2021;
d) which on or after 1 January 2017 are modified to use fuel with a flashpoint below 60°C.

Ships and vessels delivered before 1 January 2021:

a) for which the building contract was placed on or after 1 June 2009, but before 1 January 2017;
b) in the absence of a building contract, the keels of which were laid or which were at a similar stage of construction on or after 1 December 2009, but before 1 July 2017;

shall satisfy the requirements of IMO Res.MSC.285(86) "Interim guidelines on safety for natural gas-fuelled engine installations in ships" (Appendix 2) or satisfy the requirements of part B of these Regulations.

Ships and vessels delivered before 1 January 2021:

a) for which the building contract was placed before 1 June 2009;

b) in the absence of a building contract, the keels of which were laid or which were at a similar stage of construction before 1 December 2009;

shall satisfy the requirements of part B of these Regulations.

Ships to which the provisions of the third or fourth paragraph of this section are applicable shall satisfy the requirements of part C of these Regulations.

Section 3 *Accepted equipment*

Equipment constituting or forming a part of the tank or fuel system shall be accepted. Accepted equipment means equipment accepted by the Norwegian Maritime Authority based on approval or type-approval from

a) a recognised classification society;

b) other public or private institution;

c) the administration of a State that has ratified the International Convention for the Safety of Life at Sea, 1974 (SOLAS 1974), as amended.

Section 4 *Documentation*

Documentation required pursuant to these Regulations is additional to other documentation required pursuant to current applicable lists of documentation laid down by the Norwegian Maritime Authority.

For ships classed in a recognised classification society, documentation relating to the requirements of these Regulations shall be approbated by the applicable classification society prior to submission to the Norwegian Maritime Authority.

For unclassed ships, documentation relating to the requirements of these Regulations shall be submitted to the Norwegian Maritime Authority.

The Norwegian Maritime Authority may require supplementary documentation and practical tests as basis for verifying that technical arrangements and systems satisfy the requirements of these Regulations.

Part B

Chapter 2 Functional requirements and requirement for risk analysis

Section 5 *General functional requirements*

An explosion in any area or space with a potentially explosive atmosphere (in the following called "hazardous area") shall not:

a) damage accommodation in such a way that passengers or crew are harmed;

b) cause damage to any space other than the space in which the explosion occurs;

c) damage the ship in such a way that ingress of water occurs below the main deck, either by direct or progressive flooding;

d) render fire-fighting equipment outside the space damaged by the explosion inoperative;

e) damage equipment or systems in other areas that may affect the ship's propulsion or power supply;

f) damage life-saving appliances and associated launching arrangements.

On passenger ships, all equipment related to the gas installation on board shall be designed to withstand a load corresponding to the ship at 2/3 of its operational speed hitting an unyielding object head on, which extends vertically along the entire height of the ship, without resulting in consequential damage on board due to a gas discharge.

Passenger ships shall upon impact be able to withstand kinetic energy of not less than:

$$E= \frac{1}{2}(\Delta+m)v^2$$

where:

Δ = the ship's displacement, in tonnes, as mean value of lightship weight and displacement when fully immersed

m = additional mass, in tonnes, for ships due to trailing masses of water, equals to 0.1Δ.

v = speed at time of impact, in metres per second, equals 2/3 of operational speed, minimum 10 knots (5.1 m/s).

In order to estimate the forces to which the gas installation will be exposed, calculations shall be prepared that show the passenger ship's deformation length upon impact. The calculations shall be submitted to the Norwegian Maritime Authority.

On passenger ships, the gas installation shall be designed to withstand a sideways impact corresponding to 2g.

On cargo ships, critical components of the gas and control system and gas storage tanks, generators and other heavy components of the gas system, shall have such dimensions and foundations as to withstand a longitudinal retardation of 2g.

For ships with a High-Speed Craft Safety Certificate, the gas installation shall be designed to withstand accelerations as described in chapter 4 of the International Code of Safety for High-Speed Craft, adopted by Resolution MSC.97(73) (2000 HSC Code), as amended.

A propulsion engine shall withstand the stress it is subjected to upon changing from full speed ahead to full speed astern.

Section 6 *Risk analysis*

The safety level for ships shall be equivalent to the safety level for a new diesel-powered ship. The safety level shall be documented by a risk analysis based on and performed in accordance with recognised methods.

The risk analysis pursuant to the first paragraph is carried out by identifying undesired events and assessing the likelihood of such events arising and any consequences thereof.

The risk analysis shall ensure a comprehensive safety assessment of the fuel concept and the selected solutions. The analysis shall be presented as early as possible during the planning phase.

The risk analysis for high-speed craft shall be performed with a special focus on hull strength, speed and ingress damage in the event of collision.

The risk analysis shall cover the ship's systems for use and treatment of fuel, and their influence on the ship and its surroundings in the event of an undesired event. The analysis shall include the following subanalyses as described in Appendix 3:

a) concept analysis
b) emergency preparedness analysis
c) explosion analysis.

The risk analysis may be prepared as a combined publication or as separate subanalyses.

When the ship's working language is not Norwegian, the Norwegian Maritime Authority may require the analysis to be prepared in English.

The risk analysis pursuant to the first paragraph shall be updated when changes are made to the design, equipment or operational procedures during construction or after the ship is placed in service.

Chapter 3 Arrangements and design

Section 7 *Area classification*

The following areas on board are classified as Zone 1:

a) tank spaces / cold box;
b) ventilation shafts;

c) bunkering stations.

The following areas on board are classified as Zone 2:

a) gas engine rooms.

Other areas on board are classified in each individual case.

A drawing showing the area classification of hazardous areas shall be submitted to the Norwegian Maritime Authority.

Section 8 *Access*

Unauthorised persons shall be prevented by physical means from accessing hazardous areas or equipment and arrangements that are connected to the gas system.

Access to the collecting unit from bunker tanks shall so designed as to prevent access during normal operation.

There shall be no direct access to hazardous areas from accommodation spaces.

If access to hazardous areas is via an engine room that is not classified as hazardous, but has auxiliary equipment and potential electrical ignition sources, the access shall be safeguarded with a gas-lock with self-locking doors.

Section 9 *Gas engine rooms*

Gas engine rooms shall be so designed as to minimise the damage to the space and equipment placed in the space in the event of an explosion.

If the ship has two or more gas engines for propulsion with associated control systems, and engines and systems for power generation with associated distribution and wiring, they shall as a main rule be placed in separate spaces.

Gas engine rooms shall be constructed with explosion pressure relief leading to a safe area where people or equipment cannot be harmed in the event of an explosion. Explosion pressure relief to adjacent spaces may be accepted.

Gas engine rooms shall be planned with a minimum of electrical equipment. Auxiliary systems such as pumps, etc. that are connected to gas engines and that do not require placement in the gas engine room, shall be located in non-hazardous spaces.

Auxiliary systems where gas may leak directly into the system medium shall be safeguarded against gas leaks and fitted with a gas alarm.

Mechanical devices other than those required for the gas engines and the associated shaft systems shall not be installed in gas engine rooms.

Bulkheads, hulls and decks in gas engine rooms, and any explosion ducts and pressure relief spaces, shall be designed for the maximum explosion pressure that could arise for the solution in question according to the explosion analysis.

The design overpressure that the gas engine room shall withstand, shall be determined on the basis of the explosion analysis. The analysis shall take the gas engine room's geometry, design, explosion pressure relief and air-gas mixture ratio into account.

Section 10 *Emergency source of power*

The required emergency source of power shall be capable of simultaneously serving:

a) the controls for the gas ventilation arrangement;

b) ventilation of hazardous areas.

Section 11 *Tank spaces and bunker tanks*

With the exception of safety valves, it shall be possible to close all inlet and outlet valves on bunker tanks from the control room, the bridge and locally. A defect in the control system shall trigger an alarm. In the event of an emergency shutdown, the gas piping system shall be depressurised to the gas mast.

Bunker tanks for compressed gas shall be physically protected against overfilling by an early warning alarm for pressure. The maximum filling pressure shall trigger an alarm and automatically close the filling valves as well as provide pressure relief to the gas mast. The maximum filling shall not exceed the maximum filling pressure according to recommendations from the gas supplier and the classification society.

Bunker tanks for liquid gas shall be protected against overfilling by an early warning alarm and an alarm for maximum level. The maximum level shall not exceed 95% of the tank volume. Filling to the maximum level shall trigger an automatic closing of the filling valves as well as provide pressure relief to the gas mast. The automatic shutdown system shall be so arranged that it is always operative when the tank is being filled.

The early warning alarm and shutdown system for bunker tanks for compressed or liquid gas shall be independent of each other.

It shall be possible to empty, purge and vent bunker tanks and associated gas piping systems and valves.

When one tank system is non-operational, the other tank systems shall have sufficient capacity for the supply of power to the ship and for propulsion to a port.

Bunker tanks shall be placed as close as possible to the centreline.

Gas storage tanks placed in or below an area for cargo-handling operations shall have protection that reduces the risk of damage to the gas storage tank.

Section 12 *Bunkering stations*

The bunker manifold shall have a remote-controlled valve arrangement, cf. section Section 11 second paragraph.

The bunkering system shall be protected against operator errors during bunkering. This shall be documented in the risk analysis as required by section Section 6 .

The bunkering station shall be physically shielded from accommodation, cargo/working deck and control stations.

Connections and piping shall be so positioned and arranged that any damage to the gas piping does not cause damage to the ship's gas storage tank arrangement leading to uncontrolled discharge of gas.

Bunkering hoses, transfer equipment, pipes and connections shall be so arranged and equipped that electric potential is equalised.

Section 13 *Ventilation*

The ventilation shall function at all temperatures in which the ship will be operating.

The ventilation system for hazardous spaces shall be separated from the other ventilation on board.

Air intakes and outlets in hazardous spaces shall be placed at a distance preventing mixture of the airflows.

The ventilation capacity for gas engine rooms shall be at least 30 air changes per hour of the room's gross volume. Ventilation failure, reduced air circulation and operational errors shall trigger an alarm.

The ship's control stations shall be warned of operational and functional defects in the mechanical ventilation of the collecting unit from bunker tanks and ventilation shafts. The alarm shall apply to fans and airflow.

There shall be negative pressure ventilation in all hazardous spaces. When the gas engine room is located above the main deck, positive pressure ventilation may upon application be accepted as an equivalent solution.

The air intake in all hazardous technical rooms shall have replaceable filters.

Ventilation ducts to and from hazardous spaces shall be designed to withstand the maximum pressure build-up in the event of a design explosion event, cf. section Section 9 final paragraph.

Non-hazardous machinery spaces, generator rooms and control panel rooms shall have positive pressure ventilation with an air supply from a gas-safe area. Assessments shall be made to determine whether non-hazardous spaces adjacent to hazardous spaces shall be provided with ventilation. Ventilation failure shall trigger an alarm.

Section 14 *Gas piping arrangement*

Ships with one gas engine room shall have two separate supplies of fuel to gas engines placed in the gas engine room.

On passenger ships, the fuel supply to gas engines shall be carried in double piping in gas engine rooms. Other solutions for the fuel gas piping arrangement, which is part of the gas engine's fixed arrangement, may be considered by the Norwegian Maritime Authority in each individual case.

Gas piping shall not be led through other engine rooms. When double gas piping without discharge sources is used, and the danger of mechanical damage is negligible, gas may be led through another engine room when the room is equipped with a gas alarm.

Gas piping with valve arrangements shall be positioned at least 760 mm from the ship side.

Gas piping shall be protected against mechanical damage and the piping shall be capable of assimilating thermal expansion without developing substantial tension.

Section 15 *Gas detection systems*

All spaces that are defined as hazardous shall be monitored by a fixed gas detection system. The gas detection system shall be type-approved, accepted for hydrocarbon gas and for use in hazardous spaces.

The number and location of the gas detectors shall be assessed by the Norwegian Maritime Authority in each individual case. The size, gas sources and ventilation of the hazardous space will form part of the assessment. A combination of line detectors and point detectors may be used in the same room.

Gas detectors located in the exhaust duct for the engine-room ventilation shall have alarm limits of maximum 5% and 10% of the Lower Explosion Limit (LEL). Alarm limits of 5% and 10% of the LEL may also be considered in other locations where the air exchange ratio is high and where a quick dilution of the gas concentration can be expected. Other gas detectors shall have alarm limits of maximum 20% and 40% of the LEL.

Section 16 *Gas engines, regulation and control*

It shall be possible to manually trigger the emergency shutdown of each individual gas engine as well as the shutdown of the gas supply to gas engine rooms from the bridge, control room and locally near the gas engine room.

If the gas engine room ventilation is non-operational, the engine's control system shall prevent the engine from starting. A manual override of the engine-start lockout shall be possible.

Gas engines shall be fitted with a rev limiter and be safeguarded against re-ignition after the shutdown of the gas supply.

Section 17 *Fire protection*

Gas engine rooms shall be fitted with a fixed primary water-based extinguishing system. It shall be possible to activate the system from the bridge, control room and locally from a safe location outside the gas engine room.

Bulkheads and decks surrounding hazardous spaces and ventilation ducts leading to such spaces shall be insulated to a fire integrity of A-60.

Section 18 *Electrical systems*

Generators in hazardous spaces shall be brushless and insulation monitored by alarms in the event of earth faults.

Communication equipment and other fixed, handheld or portable electrical equipment in hazardous areas shall be explosion protected (Ex-protected) pursuant to the recommendations of IEC-60079-14 with regard to the nature of protection, temperature class and gas group for the zone and gas type in question. The equipment shall be adapted to the exterior environmental conditions to be expected. The ingress protection degree (IP) for generators shall comply with the supplier's recommendations for the area or location in question. Water-cooled generators shall have minimum IP 44. Air-cooled generators shall have minimum IP 22.

When transferring a flammable gas or liquid, there shall be an equalisation connection between the bunker supplier and the bunkering station on the ship.

Cable penetrations shall satisfy the requirements regulating the dispersion of gas.

Chapter 4 Testing and control of gas-related equipment and arrangements before the ship is placed in service

Section 19 *General provisions*

The company shall document that all requirements of this chapter are satisfied before the ship is placed in service.

The company shall prepare procedures for inspection and testing of all systems on board, including a plan for an 80-hour long-term test of equipment and arrangements that have not undergone a factory acceptance test in accordance with the rules of a recognised classification society. The data from the long-term test shall be submitted to the Norwegian Maritime Authority.

All technical gas-related equipment and arrangements shall be tested in accordance with specifications given in drawings documentation and manuals.

Section 20 *Gas engine testing*

The following functions and procedures for the gas engine system shall be tested on board:

a) engine-start lockout initiated by a ventilation stop in the engine room;
b) other safety functions for the gas engine systems and their arrangements.

On ships with redundant engine rooms, tests shall be carried out demonstrating that each engine room can maintain manoeuvrability, ventilation and power generation.

"Black out" tests and the tests of the machinery's ability to withstand maximum load changes shall be carried out. The tests shall be performed for each individual engine and in the relevant operational modes.

The machinery's regulating control capability at low loads shall be tested to verify critical levels.

A "crash stop" test, changing from full speed ahead to full speed astern, cf. section Section 5 .

Section 21 *Bunker tanks*

Tanks and the associated gas piping and valve arrangements shall be tested for tightness before they are filled with gas.

Pressure control valves and pressure relief valves shall be tested.

Emergency shutdown initiated by the maximum permitted filling in bunker tanks shall be tested.

Valve operations for the shutoff of fuel and venting shall be tested.

Bunker tanks shall be pressure-tested with water and dried out with hot air or hot nitrogen before they are placed in service.

Bunker tanks for liquid gas shall be cooled with nitrogen filling before the first bunkering.

Section 22 *Gas piping*

All gas piping shall be tested for tightness with an inert gas.

Section 23 *Bunkering station*

At liquid gas facilities, the bunkering station's connections and valve arrangements shall be tested by filling of liquid nitrogen according to the supplier's procedures.

In addition to the tests pursuant to the first paragraph, the following shall be performed:

a) tightness testing at actual temperatures;
b) testing of overfilling protection;
c) testing of emergency shutoff valves in the event of interrupted filling and emptying of bunker tanks and purging of gas.

Section 24 *Ventilation*

The requirements for testing and control of ventilation apply to all hazardous spaces.

The design of the ventilation system shall be tested to check that gas pockets cannot form.

The ventilation capacity shall be measured and controlled.

The ventilation system's interlocking functions in relation to the engine systems and engine rooms shall be tested.

Section 25 *Gas detection system*

The gas detection system shall be tested by exposing each individual detector to calibration gas, and by verifying that data has been registered on the right channel and with the right concentration level.

Section 26 *Thermal imaging of electrical systems*

The Norwegian Maritime Authority may require thermal imaging of electrical systems before they are put in service.

Part C
Chapter 5 Operation and maintenance

Section 27 *Procedures*

Procedures shall be prepared to take care of the safety aspects of the vessel's ordinary operation, for instance during navigation, in ports, during bunkering, at bases, oil installations and oil fields, and in repair yards.

For ships not required to hold a safety management certificate, the bunkering procedure shall be submitted to the Norwegian Maritime Authority.

Procedures for purging of gas shall be prepared. Purging of gas that takes place at a shipyard shall be performed in accordance with procedures prepared in collaboration with the shipyard.

Section 28 *Maintenance*

A maintenance manual for the gas supply system shall be available on board.

The manual as required by the first paragraph shall include maintenance procedures for all technical gas-related installations. The manual shall comply with recommendations from the suppliers of the equipment used in the gas supply system. The intervals for and the extent of replacement or recertification of the gas valves shall be established.

The maintenance procedure shall specify who is qualified to carry out the maintenance.

A special maintenance manual shall be prepared for electrical equipment that is installed in hazardous spaces and areas. The inspection and maintenance of electrical installations in hazardous spaces shall be performed in accordance with EN 60079-17.

Personnel carrying out inspections and maintenance of electrical installations in hazardous spaces shall be qualified pursuant to IEC 60079-17.

Section 29 *Special provisions for maintenance and repair work*

Engine-start lockout initiated by a ventilation stop in the engine room and other safety functions for the gas engine system shall be tested regularly in accordance with the recommendations from the equipment suppliers.

A function test of the gas detection system and test of the gas detector calibration shall be carried out in accordance with recommendations from the supplier at least once per year.

A short shutdown of the ventilation in hazardous spaces shall be carried out at regular intervals to identify minor gas leaks. Alternatively, tightness tests may be performed locally with an electronic Ex-protected measuring device.

Before maintenance work is commenced, bunker tanks and associated gas piping systems shall be emptied and purged of gas to the extent necessary.

When hot or cold work is to be carried out in hazardous spaces and areas, the gas piping system of such spaces and areas shall be purged of gas. At least two persons shall be present in the hazardous area at the same time, whereof one shall have been assigned and instructed to act as a fire watch.

The master, chief engineer officer or company shall issue a written permit for hot and cold work in hazardous areas. The permit shall include information of the time at disposal until the pressure in the bunker tanks rises to the opening pressure of the safety valves.

Inerting shall be carried out with for instance nitrogen, CO_2 or argon prior to venting. Access to the collecting unit for bunker tanks shall not be permitted until the atmosphere has been checked and determined safe.

Part D
Chapter 6 Concluding provisions

Section 30 *Equivalents and exemptions*

The Norwegian Maritime Authority may upon written application permit other solutions than those required by these Regulations when it is established that such solutions are equivalent to the requirements of the Regulations.

The Norwegian Maritime Authority may exempt a ship from one or more of the requirements of the Regulations when the company applies for an exemption in writing and one of the following conditions is met:

a) the company establishes that the requirement is not essential and that the exemption is justifiable in terms of safety;
b) the company establishes that compensating measures will maintain the same level of safety as the requirement of these Regulations.

Section 31 *Entry into force*

These Regulation enters into force on 1 January 2017. As from the same date, the Regulations of 17 June 2002 No. 644 on cargo ships with natural gas fuelled internal combustion engines and the Regulations of 9 September 20015 No. 1218 on the construction and operation of gas-fuelled passenger ships are repealed.

Appendix 1

IMO Res.MSC.391(95) "International code of safety for ships using gases or other low-flashpoint fuels"

Appendix 2

IMO Res.MSC.285(86) «Interim guidelines on safety for natural gas-fuelled engine installations in ships

Appendix 3

Implementation of risk analysis for the construction and operation of ships using fuel with a flashpoint below 60°C

INTERNATIONAL MARITIME ORGANIZATION

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MARITIME SAFETY
COMMITTEE

95th session
Agenda item 22

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REPORT OF THE MARITIME SAFETY COMMITTEE ON ITS NINETY-FIFTH SESSION

Attached is annex 1 (Resolution MSC.391(95) – Adoption of the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF Code)) to the report of the Maritime Safety Committee on its ninety-fifth session (MSC 95/22).

LIST OF ANNEXES

(See document MSC 95/22/Add.2 for annexes 2 to 27)

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ANNEX 1

RESOLUTION MSC.391(95)
(adopted on 11 June 2015)

ADOPTION OF THE INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Maritime Organization concerning the function of the Committee,

RECOGNIZING the need for a mandatory code for ships using gases or other low-flashpoint fuels,

NOTING resolution MSC.392(95), by which it adopted, inter alia, amendments to chapters II-1,II-2 and the appendix to the annex of the International Convention for the Safety of Life at Sea, 1974 ("the Convention"), to make the provisions of the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) mandatory under the Convention,

HAVING CONSIDERED, at its ninety-fifth session, the draft International Code of Safety for Ships using Gases or other Low-flashpoint Fuels,

1 ADOPTS the IGF Code, the text of which is set out in the annex to the present resolution;

2 INVITES Contracting Governments to the Convention to note that the IGF Code will take effect on 1 January 2017 upon entry into force of amendments to chapters II-1, II-2 and the appendix to the annex of the Convention;

3 INVITES ALSO Contracting Governments to consider the voluntary application of the IGF Code, as far as practicable, to cargo ships of less than 500 gross tonnage using gases or other low-flashpoint fuels;

4 RECOGNIZES that requirements for additional low-flashpoint fuels will be added to the IGF Code, as and when they are developed by the Organization;

5 REQUESTS the Secretary-General of the Organization to transmit certified copies of the present resolution and the text of the IGF Code, contained in the annex, to all Contracting Governments to the Convention;

6 REQUESTS ALSO the Secretary-General of the Organization to transmit copies of the present resolution and the text of the IGF Code contained in the annex to all Members of the Organization which are not Contracting Governments to the SOLAS Convention.

ANNEX

INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)

CONTENTS

1 PREAMBLE

The purpose of this Code is to provide an international standard for ships using low-flashpoint fuel, other than ships covered by the IGC Code.

The basic philosophy of this Code is to provide mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

Throughout the development of this Code it was recognized that it must be based upon sound naval architectural and engineering principles and the best understanding available of current operational experience, field data and research and development. Due to the rapidly evolving new fuels technology, the Organization will periodically review this Code, taking into account both experience and technical developments.

This Code addresses all areas that need special consideration for the usage of the low-flashpoint fuel. The basic philosophy of the IGF Code considers the goal based approach (MSC.1/Circ.1394). Therefore, goals and functional requirements were specified for each section forming the basis for the design, construction and operation.

The current version of this Code includes regulations to meet the functional requirements for natural gas fuel. Regulations for other low-flashpoint fuels will be added to this Code as, and when, they are developed by the Organization.

In the meantime, for other low-flashpoint fuels, compliance with the functional requirements of this Code must be demonstrated through alternative design.

PART A

2 GENERAL

2.1 Application

Unless expressly provided otherwise this Code applies to ships to which part G of SOLAS chapter II-1 applies.

2.2 Definitions

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

2.2.1 *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.

2.2.2 *Breadth (B)* means the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

2.2.3 *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.

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

2.2.5 *CNG* means compressed natural gas (see also 2.2.26).

2.2.6 *Control station* means those spaces defined in SOLAS chapter II-2 and additionally for this Code, the engine control room.

2.2.7 *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.

2.2.8 *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.

2.2.9 *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.

2.2.10 *Dual fuel engines* means engines that employ fuel covered by this Code (with pilot fuel) and oil fuel. Oil fuels may include distillate and residual fuels.

2.2.11 *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]

2.2.12 *ESD* means emergency shutdown.

[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

[2] See also definition in IEC 60092-502:1999.

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

2.2.14 *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.

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

The spaces around the fuel tank are defined as follows:

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

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

.3 *Tank connection space* is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

2.2.16 *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.

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

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

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

2.2.20 *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.

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

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

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

2.2.24 *LEL* means the lower explosive limit.

2.2.25 *Length (L)* is the length as defined in the International Convention on Load Lines in force.

2.2.26 *LNG* means liquefied natural gas.

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

2.2.28 *Low-flashpoint fuel* means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under paragraph 2.1.1 of SOLAS regulation II-2/4.

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

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

2.2.31 *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.

2.2.32 *Multi-fuel engines* means engines that can use two or more different fuels that are separate from each other.

2.2.33 *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.

2.2.34 *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.

2.2.35 *Risk i*s an expression for the combination of the likelihood and the severity of the consequences.

2.2.36 *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).

2.2.37 *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.

2.2.38 *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]

2.2.39 *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.

2.2.40 *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.

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

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

2.3 Alternative design

2.3.1 This Code contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels.

2.3.2 Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

.1 deviate from those set out in this Code, or

.2 be designed for use of a fuel not specifically addressed in this Code.

Such fuels, appliances and arrangements can be used provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

2.3.3 The equivalence of the alternative design shall be demonstrated as specified in SOLAS regulation II-1/55 and approved by the Administration. However, the Administration shall not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Code.

3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of this Code is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas or low-flashpoint fuel as fuel.

3.2 Functional requirements

3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.

3.2.2 The probability and consequences of fuel-related hazards shall 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 shall be initiated.

3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

3.2.4 Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.

3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.

3.2.7 System components shall be protected against external damages.

3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.

3.2.9 It shall 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 shall be designed to prevent venting under all normal operating conditions including idle periods.

3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.

3.2.11 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall 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.

3.2.13 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.

3.2.14 Fixed gas detection suitable for all spaces and areas concerned shall be arranged.

3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.

3.2.16 Commissioning, trials and maintenance of fuel systems and gas utilization machinery shall satisfy the goal in terms of safety, availability and reliability.

3.2.17 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

4 GENERAL REQUIREMENTS

4.1 Goal

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.

4.2 Risk assessment

4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 For ships to which part A-1 applies, the risk assessment required by 4.2.1 need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex.

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

4.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release[4] and potential ignition sources shall not:

.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 occur;

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

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

.5 damage life-saving equipment or associated launching arrangements;

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

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

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

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

PART A-1

SPECIFIC REQUIREMENTS FOR SHIPS USING NATURAL GAS AS FUEL

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

It should be recognized that the composition of natural gas may vary depending on the source of natural gas and the processing of the gas.

5 SHIP DESIGN AND ARRANGEMENT

5.1 Goal

The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.2 Functional requirements

5.2.1 This chapter is related to functional requirements in 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In particular the following apply:

.1 the fuel tank(s) shall 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 shall be so located and arranged that released gas is lead to a safe location in the open air;

.3 the access or other openings to spaces containing fuel sources of release shall 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 shall be protected against mechanical damage;

.5 the propulsion and fuel supply system shall 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 or low-flashpoint fuelled machinery shall be minimized.

5.3 Regulations – General

5.3.1 Fuel storage tanks shall be protected against mechanical damage.

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

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

.1 The fuel tanks shall 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) (refer to SOLAS regulation II-1/2.8).

.2 The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

.3 For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

.4 In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

.1 For passenger ships: B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by 5.3.3.1.

.2 For cargo ships:

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

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

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

.4 for $V_c \geq$ 30,000 m^3, 2

m, where:

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

.5 The lowermost boundary of the fuel tank(s) shall 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.

.6 For multihull ships the value of B may be specially considered.

.7 The fuel tank(s) shall be abaft a transverse plane at 0.08L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for cargo ships.

where:

L is the length as defined in the International Convention on Load Lines (refer to SOLAS regulation II-1/2.5).

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.

5.3.4 As an alternative to 5.3.3.1 above, the following calculation method may be used to determine the acceptable location of the fuel tanks:

.1 The value f_{CN} calculated as described in the following shall be less than 0.02 for passenger ships and 0.04 for cargo ships.[5]

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

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

where:

f_l is calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1. The value of x1 shall correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x 2 shall 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:

$$f_t = 1 - r(x1, x2, b)$$ [6]

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:

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

$f_v = 0.2 - 0.2 \cdot ((H - d) - 7.8)/4.7)$, in all other cases

f_v shall not be taken less than 0.

where:

H is the distance from baseline, in metres, to the lowermost boundary of the fuel tank; and

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

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5 The value f_{CN} accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel

tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

6 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.

.3 The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

.4 For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

.5 In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

.1 For passenger ships: B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by 5.3.3.1.

.2 For cargo ships:

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

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

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

.4 for $V_c \geq$ 30,000 m^3, 2

m, where:

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

.6 In case of more than one non-overlapping fuel tank located in the longitudinal direction, f_{CN} shall be calculated in accordance with paragraph 5.3.4.2 for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for f_{CN} obtained for each separate tank.

.7 In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of f_{CN} shall be calculated on both starboard and port side and the average value shall be used for the assessment. The minimum distance as set forth in paragraph 5.3.4.5 shall be met on both sides.

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.

5.3.5 When fuel is carried in a fuel containment system requiring a complete or partial secondary barrier:

.1 fuel storage hold spaces shall be segregated from the sea by a double bottom; and

.2 the ship shall also have a longitudinal bulkhead forming side tanks.

5.4 Machinery space concepts

5.4.1 In order to minimize the probability of a gas explosion in a machinery space with gas-fuelled machinery 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 shall be automatically executed while equipment or machinery in use or active during these conditions shall 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 covered by explosion pressure relief devices and ESD arrangements.

5.5 Regulations for gas safe machinery space

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

5.5.2 All fuel piping within machinery space boundaries shall be enclosed in a gas tight enclosure in accordance with 9.6.

5.6 Regulations for ESD-protected machinery spaces

5.6.1 ESD protection shall be limited to machinery spaces that are certified for periodically unattended operation.

5.6.2 Measures shall be applied to protect against explosion, damage of areas outside of the machinery space and ensure redundancy of power supply. The following arrangement shall be provided but may not be limited to:

.1 gas detector;

.2 shutoff valve;

.3 redundancy; and

.4 efficient ventilation.

5.6.3 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 shall be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces.

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

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

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

5.6.5 ESD protected machinery spaces separated by a single bulkhead shall 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.

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

5.6.7 The ventilation system of ESD-protected machinery spaces shall be arranged in accordance with 13.5.

5.7 Regulations for location and protection of fuel piping

5.7.1 Fuel pipes shall not be located less than 800 mm from the ship's side.

5.7.2 Fuel piping shall not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.

5.7.3 Fuel pipes led through ro-ro spaces, special category spaces and on open decks shall be protected against mechanical damage.

5.7.4 Gas fuel piping in ESD protected machinery spaces shall be located as far as practicable from the electrical installations and tanks containing flammable liquids.

5.7.5 Gas fuel piping in ESD protected machinery spaces shall be protected against mechanical damage.

5.8 Regulations for fuel preparation room design

Fuel preparation rooms shall be located on an open deck, unless those rooms are arranged and fitted in accordance with the regulations of this Code for tank connection spaces.

5.9 Regulations for bilge systems

5.9.1 Bilge systems installed in areas where fuel covered by this Code can be present shall be segregated from the bilge system of spaces where fuel cannot be present.

5.9.2 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 shall be provided. The bilge system shall not lead to pumps in safe spaces. Means of detecting such leakage shall be provided.

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

5.10 Regulations for drip trays

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

5.10.2 Drip trays shall be made of suitable material.

5.10.3 The drip tray shall 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.

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

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

5.11 Regulations for arrangement of entrances and other openings in enclosed spaces

5.11.1 Direct access shall not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 5.12 shall be provided.

5.11.2 If the fuel preparation room is approved located below deck, the room shall, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 5.12 shall be provided.

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

5.11.4 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances shall be arranged with an airlock which complies with 5.12.

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

5.12 Regulations for airlocks

5.12.1 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 shall not be less than 300 mm in height. The doors shall be self-closing without any holding back arrangements.

5.12.2 Airlocks shall be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.

5.12.3 The airlock shall 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 shall be evaluated in the risk analysis according to 4.2.

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

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

5.12.6 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 shall be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

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

6 FUEL CONTAINMENT SYSTEM

6.1 Goal

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.

6.2 Functional requirements

This chapter relates to functional requirements in 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.17. In particular the following apply:

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

  .1 exposure of ship materials to temperatures below acceptable limits;

  .2 flammable fuels spreading to locations with ignition sources;

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

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

  .5 reduction in availability of LSA.

.2 the pressure and temperature in the fuel tank shall be kept within the design limits of the containment system and possible carriage requirements of the fuel;

.3 the fuel containment arrangement shall 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 shall be equivalent to permanent installed tanks as described in this chapter.

6.3 Regulations – General

6.3.1 Natural gas in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 1.0 MPa.

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

6.3.3 A fuel containment system located below deck shall be gas tight towards adjacent spaces.

6.3.4 All tank connections, fittings, flanges and tank valves must be enclosed in gas tight tank connection spaces, unless the tank connections are on open deck. The space shall be able to safely contain leakage from the tank in case of leakage from the tank connections.

6.3.5 Pipe connections to the fuel storage tank shall 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 the Administration.

6.3.6 Piping between the tank and the first valve which release liquid in case of pipe failure shall have equivalent safety as the type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2.

6.3.7 The material of the bulkheads of the tank connection space shall have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario. The tank connection space shall be designed to withstand the maximum pressure build up during such a leakage. Alternatively, pressure relief venting to a safe location (mast) can be provided.

6.3.8 The probable maximum leakage into the tank connection space shall be determined based on detail design, detection and shutdown systems.

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

6.3.10 If liquefied gas fuel storage tanks are located on open deck the ship steel shall 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 shall be taken into consideration for protecting the steel structure of the ship.

6.3.11 Means shall be provided whereby liquefied gas in the storage tanks can be safely emptied.

6.3.12 It shall be possible to empty, purge and vent fuel storage tanks with fuel piping systems. Instructions for carrying out these procedures must be available on board. Inerting shall be performed with an inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipes. See detailed regulations in 6.10.

6.4 Regulations for liquefied gas fuel containment

6.4.1 General

6.4.1.1 The risk assessment required in 4.2 shall include evaluation of the ship's liquefied gas fuel containment system, and may lead to additional safety measures for integration into the overall vessel design.

6.4.1.2 The design life of fixed liquefied gas fuel containment system shall not be less than the design life of the ship or 20 years, whichever is greater.

6.4.1.3 The design life of portable tanks shall not be less than 20 years.

6.4.1.4 Liquefied gas fuel containment systems shall be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Less demanding environmental conditions, consistent with the expected usage, may be accepted by the Administration for liquefied gas fuel containment systems used exclusively for restricted navigation. More demanding environmental conditions may be required for liquefied gas fuel containment systems operated in conditions more severe than the North Atlantic environment.[7,8]

6.4.1.5 Liquefied gas fuel containment systems shall 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 shall 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.

6.4.1.6 The liquefied gas fuel containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions that shall be considered for the design of each liquefied gas fuel containment system are given in 6.4.15. There are three main categories of design conditions:

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

  .1 internal pressure;

  .2 external pressure;

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

  .4 thermal loads;

7 Refer to IACS Rec.034.

8 North Atlantic environmental conditions refer to wave conditions. Assumed temperatures are used for determining appropriate material qualities with respect to design temperatures and is another matter not intended to be covered in 6.4.1.4.

.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 shall not fail under accumulated cyclic loading.

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

.1 Collision – The liquefied gas fuel containment system shall withstand the collision loads specified in 6.4.9.5.1 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 shall sustain without rupture the rise in internal pressure specified in 6.7.3.1 under the fire scenarios envisaged therein.

.3 Flooded compartment causing buoyancy on tank – the anti-flotation arrangements shall sustain the upward force, specified in 6.4.9.5.2 and there shall 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.

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

6.4.1.8 An inspection/survey plan for the liquefied gas fuel containment system shall be developed and approved by the Administration. The inspection/survey plan shall identify aspects to be examined and/or validated during surveys throughout the liquefied gas 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 6.4.12.2.8 or 6.4.12.2.9.

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

6.4.2 Liquefied gas fuel containment safety principles

6.4.2.1 The containment systems shall 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.

6.4.2.2 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 6.4.2.3 to 6.4.2.5 as applicable.

6.4.2.3 Liquefied gas 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, shall 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).

The arrangements shall comply with the following:

.1 failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall 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 shall have a predicted development time that is much longer than the expected lifetime of the tank.

6.4.2.4 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.

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

6.4.3 Secondary barriers in relation to tank types

Secondary barriers in relation to the tank types defined in 6.4.15 shall be provided in accordance with the following table.

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

6.4.4 Design of secondary barriers

The design of the secondary barrier, including spray shield if fitted, shall be such that:

.1 it is capable of containing any envisaged leakage of liquefied gas fuel for a period of 15 days unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 6.4.12.2.6;

.2 physical, mechanical or operational events within the liquefied gas fuel tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa;

.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers;

.4 it is capable of being periodically checked for its effectiveness by means of a visual inspection or other suitable means acceptable to the Administration;

.5 the methods required in 6.4.4.4 shall be approved by the Administration and shall 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 the secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

6.4.5 Partial secondary barriers and primary barrier small leak protection system

6.4.5.1 Partial secondary barriers as permitted in 6.4.2.3 shall be used with a small leak protection system and meet all the regulations in 6.4.4.

The small leak protection system shall 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.

6.4.5.2 The capacity of the partial secondary barrier shall be determined, based on the liquefied gas fuel leakage corresponding to the extent of failure resulting from the load spectrum referred to in 6.4.12.2.6, 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.

6.4.5.3 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.

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

6.4.6 Supporting arrangements

6.4.6.1 The liquefied gas fuel tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 6.4.9.2 to 6.4.9.5, 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.

6.4.6.2 Anti-flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in 6.4.9.5.2 without plastic deformation likely to endanger the hull structure.

6.4.6.3 Supports and supporting arrangements shall withstand the loads defined in 6.4.9.3.3.8 and 6.4.9.5, but these loads need not be combined with each other or with wave-induced loads.

6.4.7 Associated structure and equipment

6.4.7.1 Liquefied gas fuel containment systems shall 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).

6.4.8 Thermal insulation

6.4.8.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable (see 6.4.13.1.1) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in 6.9.

6.4.9 Design loads

6.4.9.1 *General*

6.4.9.1.1 This section defines the design loads that shall be considered with regard to regulations in 6.4.10 to 6.4.12. This includes load categories (permanent, functional, environmental and accidental) and the description of the loads.

6.4.9.1.2 The extent to which these loads shall be considered depends on the type of tank, and is more fully detailed in the following paragraphs.

6.4.9.1.3 Tanks, together with their supporting structure and other fixtures, shall be designed taking into account relevant combinations of the loads described below.

6.4.9.2 *Permanent loads*

6.4.9.2.1 Gravity loads

The weight of tank, thermal insulation, loads caused by towers and other attachments shall be considered.

6.4.9.2.2 Permanent external loads

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

6.4.9.3 *Functional loads*

6.4.9.3.1 Loads arising from the operational use of the tank system shall be classified as functional loads.

6.4.9.3.2 All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered.

6.4.9.3.3 As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

(a) internal pressure

(b) external pressure

(c) thermally induced loads

(d) vibration

(e) interaction loads

(f) loads associated with construction and installation

(g) test loads

(h) static heel loads

(i) weight of liquefied gas fuel

(j) sloshing

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

6.4.9.3.3.1 Internal pressure

.1 In all cases, including 6.4.9.3.3.1.2, P_0 shall not 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 shall not be less than the gauge vapour pressure of the liquefied gas fuel at a temperature of 45°C except as follows:

.1 Lower values of ambient temperature may be accepted by the Administration for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

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

.3 Subject to special consideration by the Administration and to the limitations given in 6.4.15 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 shall be:

.1 $(P_g)_{max}$ is the associated liquid pressure determined using the maximum design accelerations.

.2 $(P_{g\ site})_{max}$ is the associated liquid pressure determined using site specific accelerations.

.3 P_{eq} should be the greater of P_{eq1} and P_{eq2} calculated as follows:

$$P_{eq1} = P_0 + (P_g)_{max} \text{ (MPa)},$$

$$P_{eq2} = P_h + (P_{g\ site})_{max} \text{ (MPa)}.$$

.5 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the liquefied gas fuel due to the motions of the ship referred to in 6.4.9.4.1.1. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations shall be calculated as follows:

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

where:

α_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads,

in an arbitrary direction β; (see figure 6.4.1).

For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, should 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 β direction (see figure 6.4.2).

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

where:

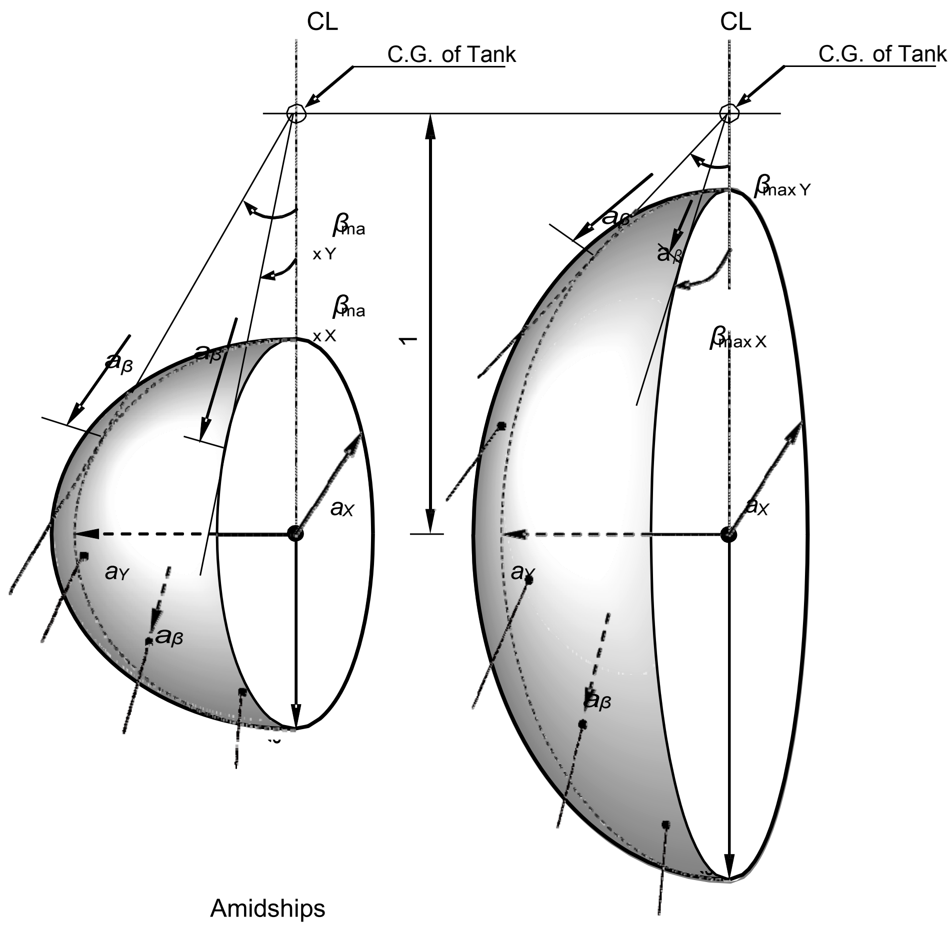
$$V_d = V_t \left(\frac{100 - FL}{FL} \right)$$

V_t = tank volume without any domes; and

FL = filling limit according to 6.8.

ρ = maximum liquefied gas fuel density (kg/m^3) at the design temperature.

The direction that gives the maximum value ($\square_g$)$\square\square x$ or ($\square_g$ $\square i \square\square$)$\square\square x$ shall be considered. Where acceleration components in three directions need to be considered, an ellipsoid shall be used instead of the ellipse in figure 6.4.1. The above formula applies only to full tanks.



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

a_X = longitudinal component of acceleration

a_Y = transverse component of acceleration

At 0.05L from FP

a_Z = vertical component of acceleration (refer to 6.4.9.4.1.1)

Figure 6.4.1 – Acceleration ellipsoid

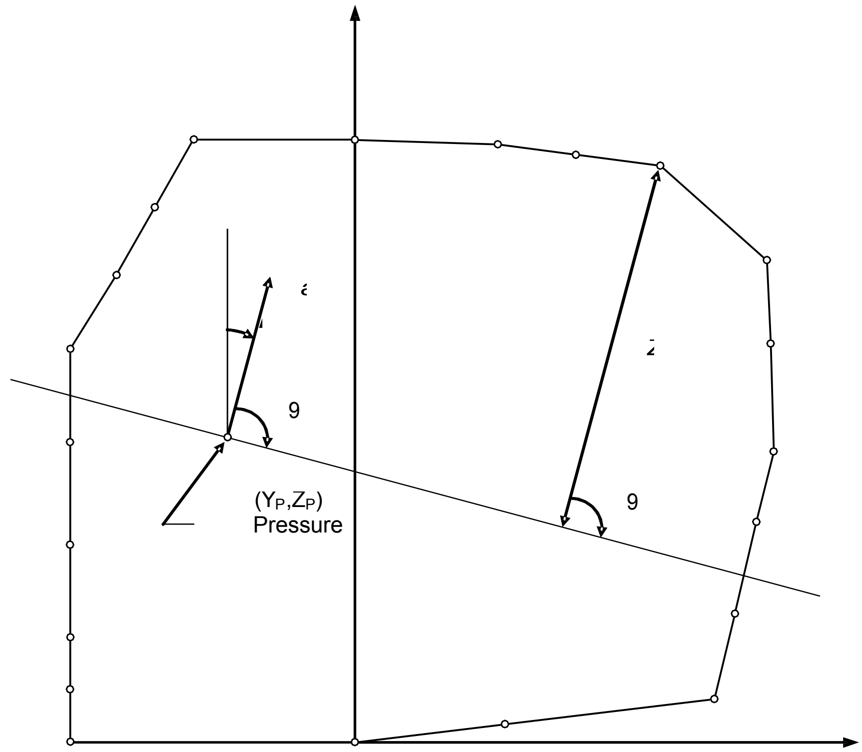


Figure 6.4.2 – Determination of internal pressure heads

6.4.9.3.3.2 External pressure

External design pressure loads shall 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.

6.4.9.3.3.3 Thermally induced loads

6.4.9.3.3.3.1 Transient thermally induced loads during cooling down periods shall be considered for tanks intended for liquefied gas fuel temperatures below minus 55°C.

6.4.9.3.3.3.2 Stationary thermally induced loads shall 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 (see paragraph 6.9.2).

6.4.9.3.3.4 Vibration

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

6.4.9.3.3.5 Interaction loads

The static 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, shall be considered.

6.4.9.3.3.6 Loads associated with construction and installation

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

6.4.9.3.3.7 Test loads

Account shall be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in 16.5.

6.4.9.3.3.8 Static heel loads

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30°shall be considered.

6.4.9.3.3.9 Other loads

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

6.4.9.4 Environmental loads

6.4.9.4.1 Environmental loads are defined as those loads on the liquefied gas fuel containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

6.4.9.4.1.1 Loads due to ship motion

The determination of dynamic loads shall 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 shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:

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

.2 transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and

.3 longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

Methods to predict accelerations due to ship motion shall be proposed and approved by the Administration[9].

Ships for restricted service may be given special consideration.

9 Refer to section 4.28.2.1 of the IGC Code for guidance formulae for acceleration components.

6.4.9.4.1.2 Dynamic interaction loads

Account shall 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.

6.4.9.4.1.3 Sloshing loads

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

6.4.9.4.1.4 Snow and ice loads

Snow and icing shall be considered, if relevant.

6.4.9.4.1.5 Loads due to navigation in ice

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

6.4.9.4.1.6 Green sea loading

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

6.4.9.4.1.7 Wind loads

Account shall be taken to wind generated loads as relevant.

6.4.9.5 Accidental loads

Accidental loads are defined as loads that are imposed on a liquefied gas fuel containment system and it's supporting arrangements under abnormal and unplanned conditions.

6.4.9.5.1 Collision load

The collision load shall 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.

Ship length (L)	Design acceleration (a)
L > 100 m	0,5 g
60 < L ≤ 100 m	$\left(2 - \frac{3(L - 60)}{80}\right) g$
L ≤ 60 m	2g

Special consideration should be given to ships with Froude number (Fn) > 0,4.

6.4.9.5.2 Loads due to flooding on ship

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

6.4.10 Structural integrity

6.4.10.1 General

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

6.4.10.1.2 The structural integrity of liquefied gas fuel containment systems can be demonstrated by compliance with 6.4.15, as appropriate for the liquefied gas fuel containment system type.

6.4.10.1.3 For other liquefied gas fuel containment system types, that are of novel design or differ significantly from those covered by 6.4.15, the structural integrity shall be demonstrated by compliance with 6.4.16.

6.4.11 Structural analysis

6.4.11.1 *Analysis*

6.4.11.1.1 The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.

6.4.11.1.2 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.

6.4.11.1.3 When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.

6.4.11.2 *Load scenarios*

6.4.11.2.1 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 shall be considered.

6.4.11.2.2 The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service conditions shall be considered.

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

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

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

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

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

xy xy.st

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\sum \quad xz.}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\sum \quad yz.}$$

where:

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

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

each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

6.4.12 Design conditions

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this chapter, and the load scenarios are covered by 6.4.11.2.

6.4.12.1 *Ultimate design condition*

6.4.12.1.1 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 this Code:

.1 Plastic deformation and buckling shall be considered.

.2 Analysis shall 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.

.3 For the purpose of ultimate strength assessment the following material parameters apply:

.1 R_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, shall be used. In such cases the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in liquefied gas fuel containment systems.

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

.4 The equivalent stress σ_c (von Mises, Huber) shall be determined by:

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

where:

σ_x = total normal stress in x-direction;
σ_y = total normal stress in y-direction;
σ_z = total normal stress in z-direction;
τ_{xy} = total shear stress in x-y plane;
τ_{xz} = total shear stress in x-z plane; and
τ_{yz} = total shear stress in y-z plane.

The above values shall be calculated as described in 6.4.11.2.3.

.5 Allowable stresses for materials other than those covered by 7.4 shall be subject to approval by the Administration in each case.

.6 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

6.4.12.2 *Fatigue Design Condition*

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

.2 Where a fatigue analysis is required the cumulative effect of the fatigue load shall comply with:

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_W$$

where:

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

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

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

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

▯$_{▯}$ = maximum allowable cumulative fatigue damage ratio.

The fatigue damage shall 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 shall 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 shall be given to various filling conditions.

.4 Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

The S-N curves shall 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 6.4.12.2.7 to 6.4.12.2.9.

.5 Analysis shall 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

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

.6 Where the size of the secondary barrier is reduced, as is provided for in 6.4.2.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

.1 crack propagation paths in the structure, where necessitated by 6.4.12.2.7 to 6.4.12.2.9, 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. Methods for fatigue crack growth analysis and fracture mechanics shall be based on recognized standards.

In analysing crack propagation the largest initial crack not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable.

Crack propagation analysis specified in 6.4.12.2.7 the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in figure 6.4.3. Load distribution and sequence for longer periods, such as in 6.4.12.2.8 and 6.4.12.2.9 shall be approved by the Administration.

The arrangements shall comply with 6.4.12.2.7 to 6.4.12.2.9 as applicable.

.7 For failures that can be reliably detected by means of leakage detection:

C_w shall 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, shall not be less than 15 days unless different regulations apply for ships engaged in particular voyages.

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

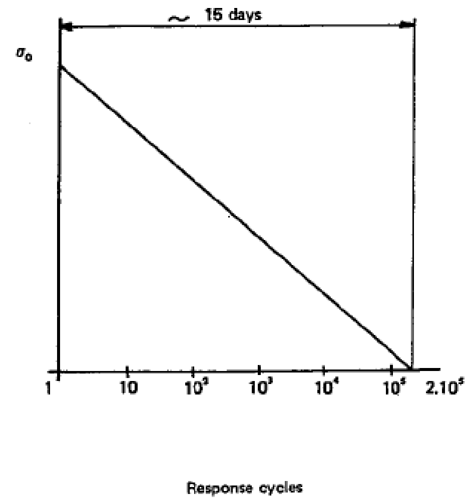
C_w shall be less than or equal to 0.5.

Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three (3) times the inspection interval.

.9 In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum:

C_w shall be less than or equal to 0.1.

Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three (3) times the lifetime of the tank.



σ_o = 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 6.4.3 – Simplified load distribution

6.4.12.3 *Accidental design condition*

6.4.12.3.1 The accidental design condition is a design condition for accidental loads with extremely low probability of occurrence.

6.4.12.3.2 Analysis shall be based on the characteristic values as follows:

Permanent loads	Expected values
Functional loads	Specified values
Environmental loads	Specified values
Accidental loads	Specified values or expected values

Loads mentioned in 6.4.9.3.3.8 and 6.4.9.5 need not be combined with each other or with wave-induced loads.

6.4.13 Materials and construction

6.4.13.1 Materials

6.4.13.1.1 Materials forming ship structure

6.4.13.1.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types. The following assumptions shall be made in this calculation:

.1 The primary barrier of all tanks shall 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 shall be assumed to be at the liquefied gas fuel temperature at atmospheric pressure for any one tank only.

.3 For worldwide service, ambient temperatures shall 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 the Administration for ships trading to areas where lower temperatures are expected during the winter months.

.4 Still air and sea water conditions shall 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 as defined in 6.4.13.3.6 and 6.4.13.3.7 shall be assumed.

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

.7 Credit for hull heating may be taken in accordance with 6.4.13.1.1.3, provided the heating arrangements are in compliance with 6.4.13.1.1.4.

.8 No credit shall be given for any means of heating, except as described in 6.4.13.1.1.3.

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

6.4.13.1.1.2 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, shall be in accordance with table 7.5. 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.

6.4.13.1.1.3 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 7.5. In the calculations required in 6.4.13.1.1.1, 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 6.4.13.1.1.2 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 6.4.13.1.1.3.2, 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 6.4.13.1.1.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.

6.4.13.1.1.4 The means of heating referred to in 6.4.13.1.1.3 shall comply with the following:

.1 the heating system shall 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 shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 6.4.13.1.1.3.1 shall be supplied from the emergency source of electrical power; and

.3 the design and construction of the heating system shall be included in the approval of the containment system by the Administration.

6.4.13.2 Materials of primary and secondary barriers

6.4.13.2.1 Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with table 7.1, 7.2 or 7.3.

6.4.13.2.2 Materials, either non-metallic or metallic but not covered by tables 7.1, 7.2 and 7.3, used in the primary and secondary barriers may be approved by the Administration considering the design loads that they may be subjected to, their properties and their intended use.

6.4.13.2.3 Where non-metallic materials,[10] including composites, are used for or incorporated in the primary or secondary barriers, they shall 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.

6.4.13.2.4 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than minus196°C.

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

6.4.13.2.6 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.

6.4.13.3 Thermal insulation and other materials used in liquefied gas fuel containment systems

6.4.13.3.1 Load-bearing thermal insulation and other materials used in liquefied gas fuel containment systems shall be suitable for the design loads.

6.4.13.3.2 Thermal insulation and other materials used in liquefied gas fuel containment systems shall 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;

10 Refer to section 6.4.16.

.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.

6.4.13.3.3 The above properties, where applicable, shall 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.

6.4.13.3.4 Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall 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 shall 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.

6.4.13.3.5 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.

6.4.13.3.6 Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

6.4.13.3.7 Where powder or granulated thermal insulation is used, measures shall 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.

6.4.14 Construction processes

6.4.14.1 Weld joint design

6.4.14.1.1 All welded joints of the shells of independent tanks shall 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.

6.4.14.1.2 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, shall be as follows:

.1 All longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels.[11] Other edge preparations may be 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 shall be designed according to a standard acceptable to the Administration. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

6.4.14.2 Design for gluing and other joining processes

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

6.4.15 Tank types

6.4.15.1 Type A independent tanks

6.4.15.1.1 Design basis

6.4.15.1.1.1 Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with the requirements of the Administration. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_0 shall be less than 0.07 MPa.

6.4.15.1.1.2 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed in accordance with 6.4.4.

6.4.15.1.2 Structural analysis

6.4.15.1.2.1 A structural analysis shall be performed taking into account the internal pressure as indicated in 6.4.9.3.3.1, and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.

6.4.15.1.2.2 For parts, such as structure in way of supports, not otherwise covered by the regulations in this Code, stresses shall be determined by direct calculations, taking into account the loads referred to in 6.4.9.2 to 6.4.9.5 as far as applicable, and the ship deflection in way of supports.

6.4.15.1.2.3 The tanks with supports shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads.

[11] For vacuum insulated tanks without manhole, the longitudinal and circumferential joints should meet the

aforementioned requirements, except for the erection weld joint of the outer shell, which may be a one-side welding with backing rings.

6.4.15.1.3 Ultimate design condition

6.4.15.1.3.1 For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of $R_m/2.66$ or $R_e/1.33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_e are defined in 6.4.12.1.1.3. However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c, as defined in 6.4.12.1.1.4, may be increased over that indicated above to a stress acceptable to the Administration. Calculations shall take into account the effects of bending, shear, axial and torsional 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.

6.4.15.1.3.2 Tank boundary scantlings shall meet at least the requirements of the Administration for deep tanks taking into account the internal pressure as indicated in 6.4.9.3.3.1 and any corrosion allowance required by 6.4.1.7.

6.4.15.1.3.3 The liquefied gas fuel tank structure shall be reviewed against potential buckling.

6.4.15.1.4 Accidental design condition

6.4.15.1.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3 as relevant.

6.4.15.1.4.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.1.3, modified as appropriate taking into account their lower probability of occurrence.

6.4.15.2 Type B independent tanks

6.4.15.2.1 Design basis

6.4.15.2.1.1 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 shall be less than 0.07 MPa.

6.4.15.2.1.2 A partial secondary barrier with a protection system is required as defined in 6.4.3. The small leak protection system shall be designed according to 6.4.5.

6.4.15.2.2 Structural analysis

6.4.15.2.2.1 The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

.1 plastic deformation;

.2 buckling;

.3 fatigue failure; and

.4 crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, shall be carried out.

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

6.4.15.2.2.3 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, shall be performed unless the data is available from similar ships.

6.4.15.2.3 Ultimate design condition

6.4.15.2.3.1 Plastic deformation

For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5F$
$\sigma_L+\sigma_b \leq 1.5F$
$\sigma_m+\sigma_b \leq 1.5F$
$\sigma_m+\sigma_b+\sigma_g \leq 3.0F$
$\sigma_L+\sigma_b+\sigma_g \leq 3.0F$

where:

σ_m = equivalent primary general membrane stress;

σ_L = equivalent primary local membrane stress;

σ_b = equivalent primary bending stress;

σ_g = equivalent secondary stress;

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

F = the lesser of (R_m / C) or (R_e / D),

with R_m and R_e as defined in 6.4.12.1.1.3. With regard to the stresses σ_m, σ_L, σ_g and σ_b see also the definition of stress categories in 6.4.15.2.3.6.

The values A and B shall have at least the following minimum values:

	Nickel steels and carbon manganese steels	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

The above figures may be altered considering the design condition considered in acceptance with the Administration. For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not 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 $R_e/1.2$; and

.3 for aluminium alloys, the lesser of $R_m/2.5$ or $R^e/1.2$.

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

The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

6.4.15.2.3.2 Buckling

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

6.4.15.2.3.3 Fatigue design condition

6.4.15.2.3.3.1 Fatigue and crack propagation assessment shall be performed in accordance with the provisions of 6.4.12.2. The acceptance criteria shall comply with 6.4.12.2.7, 6.4.12.2.8 or 6.4.12.2.9, depending on the detectability of the defect.

6.4.15.2.3.3.2 Fatigue analysis shall consider construction tolerances.

6.4.15.2.3.3.3 Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

6.4.15.2.3.4 Accidental design condition

6.4.15.2.3.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3, as relevant.

6.4.15.2.3.4.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.2.3, modified as appropriate, taking into account their lower probability of occurrence.

6.4.15.2.3.5 Marking

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

6.4.15.2.3.6 Stress categories

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:

$d_1 \leq 0.5\sqrt{Rt}$; and

$d_2 \geq 2.5\sqrt{Rt}$

where:

d_1 = distance in the meridional direction over which the equivalent stress exceeds $1.1f$;

d_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded;

R = mean radius of the vessel;

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

□ = 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.

6.4.15.3 Type C independent tanks

6.4.15.3.1 Design basis

6.4.15.3.1.1 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 6.4.15.3.1.2 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.

6.4.15.3.1.2 The design vapour pressure shall not be less than:

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

where:

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

with:

σ_m = design primary membrane stress;

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

- 55 N/mm² for ferritic-perlitic, martensitic and austenitic steel;
- 25 N/mm² for aluminium alloy (5083-O);

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

h, 0.75*b* or 0.45*ℓ*,

with:

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.

6.4.15.3.2 Shell thickness

6.4.15.3.2.1 In considering the shell thickness the following apply:

.1 for pressure vessels, the thickness calculated according to 6.4.15.3.2.4 shall 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, shall not be less than 5 mm for carbon manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys; and

.3 the welded joint efficiency factor to be used in the calculation according to 6.4.15.3.2.4 shall be 0.95 when the inspection and the non-destructive testing referred to in 16.3.6.4 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 the Administration may accept partial non-destructive examinations, but not less than those of 16.3.6.4, depending on such 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 shall be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

6.4.15.3.2.2 The design liquid pressure defined in 6.4.9.3.3.1 shall be taken into account in the internal pressure calculations.

6.4.15.3.2.3 The design external pressure P_e, used for verifying the buckling of the pressure vessels, shall not 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 shall be specially considered, but shall not in general 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 shall be taken into account.

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

6.4.15.3.2.4 Scantlings based on internal pressure shall be calculated as follows:

The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 6.4.9.3.3.1, including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with a recognized standard acceptable to the Administration.

6.4.15.3.2.5 Stress analysis in respect of static and dynamic loads shall be performed as follows:

.1 pressure vessel scantlings shall be determined in accordance with 6.4.15.3.2.1 to 6.4.15.3.2.4 and 6.4.15.3.3;

.2 calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in 6.4.9.2 to 6.4.9.5 shall be used, as applicable. Stresses in way of the supports shall be to a recognized standard acceptable to the Administration. In special cases a fatigue analysis may be required by the Administration; and

.3 if required by the Administration, secondary stresses and thermal stresses shall be specially considered.

6.4.15.3.3 Ultimate design condition

6.4.15.3.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not 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; and

f = the lesser of R_m/A or R_e/B,

with R_m and R_e as defined in 6.4.12.1.1.3. With regard to the stresses σ_m, σ_L, σ_g and σ_b see also the definition of stress categories in 6.4.15.2.3.6. The values A and B shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3.5	4
B	1.5	1.5	1.5

6.4.15.3.3.2 Buckling criteria shall be as follows:

The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall 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.

6.4.15.3.4 Fatigue design condition

6.4.15.3.4.1 For type C independent tanks where the liquefied gas fuel at atmospheric pressure is below minus 55°C, the Administration may require additional verification to check their compliance with 6.4.15.3.1.1, regarding static and dynamic stress depending on the tank size, the configuration of the tank and arrangement of its supports and attachments.

6.4.15.3.4.2 For vacuum insulated tanks, special attention shall be made to the fatigue strength of the support design and special considerations shall also be made to the limited inspection possibilities between the inside and outer shell.

6.4.15.3.5 Accidental design condition

6.4.15.3.5.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3, as relevant.

6.4.15.3.5.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.3.3.1, modified as appropriate taking into account their lower probability of occurrence.

6.4.15.3.6 Marking

The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

6.4.15.4 Membrane tanks

6.4.15.4.1 Design basis

6.4.15.4.1.1 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.

6.4.15.4.1.2 A systematic approach, based on analysis and testing, shall be used to demonstrate that the system will provide its intended function in consideration of the identified in service events as specified in 6.4.15.4.2.1.

6.4.15.4.1.3 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed according to 6.4.4.

6.4.15.4.1.4 The design vapour pressure P_0 shall not normally 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.

6.4.15.4.1.5 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.

6.4.15.4.1.6 The thickness of the membranes shall normally not exceed 10 mm.

6.4.15.4.1.7 The circulation of inert gas throughout the primary and the secondary insulation spaces, in accordance with 6.11.1 shall be sufficient to allow for effective means of gas detection.

6.4.15.4.2 Design considerations

6.4.15.4.2.1 Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

.1 Ultimate design events:

- .1 tensile failure of membranes;
- .2 compressive collapse of thermal insulation;
- .3 thermal ageing;
- .4 loss of attachment between thermal insulation and hull structure;
- .5 loss of attachment of membranes to thermal insulation system;
- .6 structural integrity of internal structures and their associated supporting structures; and
- .7 failure of the supporting hull structure.

.2 Fatigue design events:

- .1 fatigue of membranes including joints and attachments to hull structure;
- .2 fatigue cracking of thermal insulation;
- .3 fatigue of internal structures and their associated supporting structures; and
- .4 fatigue cracking of inner hull leading to ballast water ingress.

.3 Accident design events:

- .1 accidental mechanical damage (such as dropped objects inside the tank while in service);
- .2 accidental over pressurization of thermal insulation spaces;
- .3 accidental vacuum in the tank; and
- .4 water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

6.4.15.4.2.2 The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the liquefied gas fuel containment system shall be established during the design development in accordance with 6.4.15.4.1.2.

6.4.15.4.3 Loads, load combinations

Particular consideration shall be paid to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the liquefied gas fuel tank, the sloshing effects, to hull vibration effects, or any combination of these events.

6.4.15.4.4 Structural analyses

6.4.15.4.4.1 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 shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the liquefied gas fuel containment system.

6.4.15.4.4.2 Structural analyses of the hull shall take into account the internal pressure as indicated in 6.4.9.3.3.1. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

6.4.15.4.4.3 The analyses referred to in 6.4.15.4.4.1 and 6.4.15.4.4.2 shall be based on the particular motions, accelerations and response of ships and liquefied gas fuel containment systems.

6.4.15.4.5 Ultimate design condition

6.4.15.4.5.1 The structural resistance of every critical component, sub-system, or assembly, shall be established, in accordance with 6.4.15.4.1.2, for in-service conditions.

6.4.15.4.5.2 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, shall reflect the consequences associated with the considered mode of failure.

6.4.15.4.5.3 The inner hull scantlings shall meet the regulations for deep tanks, taking into account the internal pressure as indicated in 6.4.9.3.3.1 and the specified appropriate regulations for sloshing load as defined in 6.4.9.4.1.3.

6.4.15.4.6 Fatigue design condition

6.4.15.4.6.1 Fatigue analysis shall 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.

6.4.15.4.6.2 The fatigue calculations shall be carried out in accordance with 6.4.12.2, with relevant regulations depending on:

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

.2 availability for inspection.

6.4.15.4.6.3 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 shall be less than or equal to 0.5.

6.4.15.4.6.4 Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics regulations stated in 6.4.12.2.8.

6.4.15.4.6.5 Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics regulations stated in 6.4.12.2.9.

6.4.15.4.7 Accidental design condition

6.4.15.4.7.1 The containment system and the supporting hull structure shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads.

6.4.15.4.7.2 Additional relevant accidental scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks.

6.4.16 Limit state design for novel concepts

6.4.16.1 Fuel containment systems that are of a novel configuration that cannot be designed using section 6.4.15 shall be designed using this section and 6.4.1 to 6.4.14, as applicable. Fuel containment system design according to this section shall 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 using 6.4.15.

6.4.16.2.1 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 6.4.1.6. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.

6.4.16.2.2 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 degradation 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.

6.4.16.3 The procedure and relevant design parameters of the limit state design shall 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 the annex to part A-1.

6.5 Regulations for portable liquefied gas fuel tanks

6.5.1 The design of the tank shall comply with 6.4.15.3. The tank support (container frame or truck chassis) shall be designed for the intended purpose.

6.5.2 Portable fuel tanks shall 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.

6.5.3 Portable fuel tanks shall be secured to the deck while connected to the ship systems. The arrangement for supporting and fixing the tanks shall 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.

6.5.4 Consideration shall be given to the strength and the effect of the portable fuel tanks on the ship's stability.

6.5.5 Connections to the ship's fuel piping systems shall be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.

6.5.6 Arrangements shall be provided to limit the quantity of fuel spilled in case of inadvertent disconnection or rupture of the non-permanent connections.

6.5.7 The pressure relief system of portable tanks shall be connected to a fixed venting system.

6.5.8 Control and monitoring systems for portable fuel tanks shall be integrated in the ship's control and monitoring system. Safety system for portable fuel tanks shall be integrated in the ship's safety system (e.g. shutdown systems for tank valves, leak/gas detection systems).

6.5.9 Safe access to tank connections for the purpose of inspection and maintenance shall be ensured.

6.5.10 After connection to the ship's fuel piping system,

.1 with the exception of the pressure relief system in 6.5.6 each portable tank shall be capable of being isolated at any time;

.2 isolation of one tank shall not impair the availability of the remaining portable tanks; and

.3 the tank shall not exceed its filling limits as given in 6.8.

6.6 Regulations for CNG fuel containment

6.6.1 The storage tanks to be used for CNG shall be certified and approved by the Administration.

6.6.2 Tanks for CNG shall be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 6.7.2.7 and 6.7.2.8.

6.6.3 Adequate means shall be provided to depressurize the tank in case of a fire which can affect the tank.

6.6.4 Storage of CNG in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Administration provided the following is fulfilled in addition to 6.3.4 to 6.3.6:

.1 adequate means are provided to depressurize and inert the tank in case of a fire which can affect the tank;

.2 all surfaces within such enclosed spaces containing the CNG storage are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the enclosed spaces containing the CNG storage. Special consideration should be given to the extinguishing of jet-fires.

6.7 Regulations for pressure relief system

6.7.1 *General*

6.7.1.1 All fuel storage tanks shall 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, shall also be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 shall be independent of the pressure relief systems.

6.7.1.2 Fuel storage tanks which may be subject to external pressures above their design pressure shall be fitted with vacuum protection systems.

6.7.2 Pressure relief systems for liquefied gas fuel tanks

6.7.2.1 If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space shall be protected by a pressure relief device which shall be connected to a vent system if the tanks are located below deck. On open deck a direct release into the atmosphere may be accepted by the Administration for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.

6.7.2.2 Liquefied gas fuel tanks shall be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

6.7.2.3 Interbarrier spaces shall be provided with pressure relief devices.[12] For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

6.7.2.4 The setting of the PRVs shall not 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.

6.7.2.5 The following temperature regulations apply to PRVs fitted to pressure relief systems:

.1 PRVs on fuel tanks with a design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation;

.2 the effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs;

.3 PRVs shall 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 shall be of suitably robust construction to prevent damage.

6.7.2.6 In the event of a failure of a fuel tank PRV a safe means of emergency isolation shall be available.

.1 procedures shall be provided and included in the operation manual (refer to chapter 18);

.2 the procedures shall allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks shall be included to this effect; and

.3 isolation of the PRV shall be carried out under the supervision of the master. This action shall be recorded in the ship's log, and at the PRV.

6.7.2.7 Each pressure relief valve installed on a liquefied gas fuel tank shall be connected to a venting system, which shall be:

.1 so constructed that the discharge will be unimpeded and normally 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 shall normally not be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways. However, vent mast height could be limited to lower value according to special consideration by the Administration.

12 Refer to IACS Unified Interpretation GC9 entitled *Guidance for sizing pressure relief systems for interbarrier spaces, 1988*.

6.7.2.8 The outlet from the pressure relief valves shall 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.

6.7.2.9 All other fuel gas vent outlets shall also be arranged in accordance with 6.7.2.7 and 6.7.2.8. Means shall be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

6.7.2.10 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

6.7.2.11 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.

6.7.2.12 All vent piping shall 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.

6.7.2.13 PRVs shall be connected to the highest part of the fuel tank. PRVs shall be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL) as given in 6.8, under conditions of 15° list and 0.015L trim, where L is defined in 2.2.25.

6.7.3 Sizing of pressure relieving system

6.7.3.1 *Sizing of pressure relief valves*

6.7.3.1.1 PRVs shall 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:

$$Q = FGA^{0.82} \text{ (m}^3\text{/s)}$$

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 the Administration. (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 shall 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 shall be used;

Z = compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 shall be used;

M = molecular mass of the product.

The gas factor of each liquefied gas fuel to be carried is to be determined and the highest value shall be used for PRV sizing.

A = external surface area of the tank (m^2), as for different tank types, as shown in figure 6.7.1.

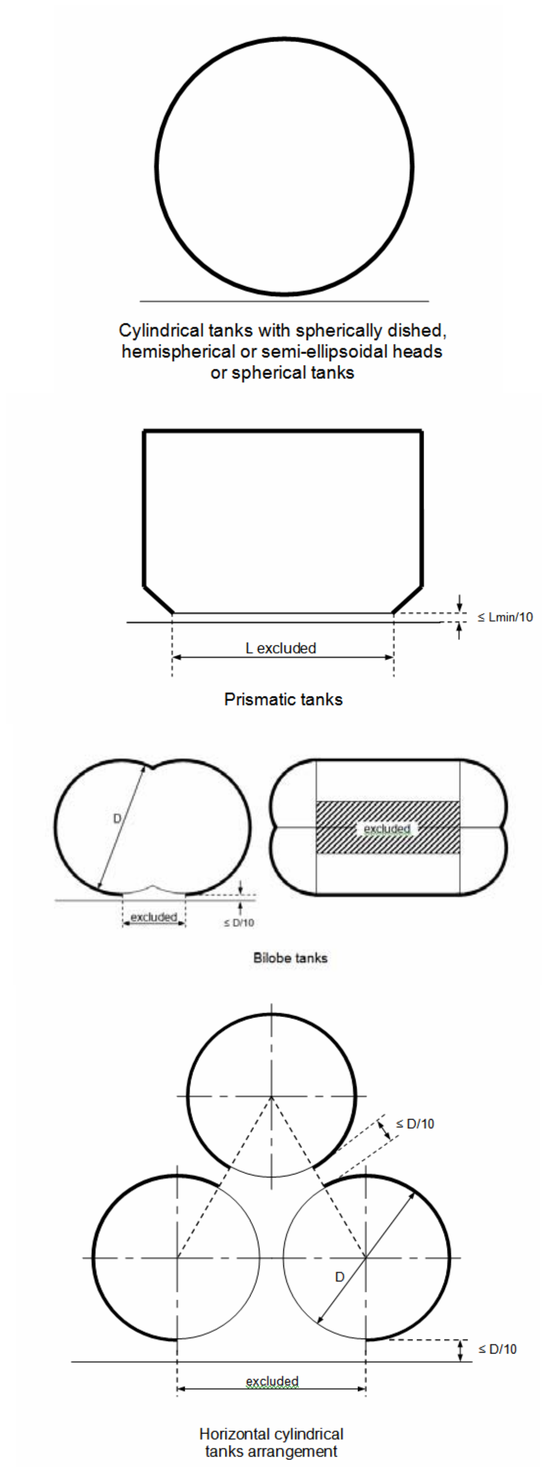


Figure 6.7.1

6.7.3.1.2 For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by 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:

□ = 0.5 to □ = 0.25

□ = 0.2 to □ = 0.1

The minimum fire factor is □= 0.1

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

M_{air} = □ * ρ_{air} (kg/s)

where density of air (ρ_{air}) = 1.293 kg/m^3 (air at 273.15 K, 0.1013 MPa).

6.7.3.2 Sizing of vent pipe system

6.7.3.2.1 Pressure losses upstream and downstream of the PRVs, shall be taken into account when determining their size to ensure the flow capacity required by 6.7.3.1.

6.7.3.2.2 Upstream pressure losses

.1 the pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 6.7.3.1;

.2 pilot-operated PRVs shall 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 shall be considered for flowing type pilots.

6.7.3.2.3 Downstream pressure losses

.1 Where common vent headers and vent masts are fitted, calculations shall 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, shall not exceed the following values:

.1 for unbalanced PRVs: 10% of MARVS;

.2 for balanced PRVs: 30% of MARVS; and

.3 for pilot operated PRVs: 50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

6.7.3.2.4 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.

6.8 Regulations on loading limit for liquefied gas fuel tanks

6.8.1 Storage tanks for liquefied gas shall not be filled to more than a volume equivalent to 98% full at the reference temperature as defined in 2.2.36.

A loading limit curve for actual fuel loading temperatures shall 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.

6.8.2 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 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 6.9). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in 6.8.1 shall be used.

6.9 Regulations for the maintaining of fuel storage condition

6.9.1 *Control of tank pressure and temperature*

6.9.1.1 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 shall be maintained at all times within their design range by means acceptable to the Administration, 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 shall 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.

6.9.1.2 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.

6.9.2 ***Design of systems***

6.9.2.1 For worldwide service, the upper ambient design temperature shall be sea 32°C and air 45°C. For service in particularly hot or cold zones, these design temperatures shall be increased or decreased, to the satisfaction of the Administration.

6.9.2.2 The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

6.9.3 ***Reliquefaction systems***

6.9.3.1 The reliquefaction system shall be designed and calculated according to 6.9.3.2. The system has to be sized in a sufficient way also in case of no or low consumption.

6.9.3.2 The reliquefaction system shall 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; or

.4 if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases shall, as far as reasonably practicable, be disposed of without venting to atmosphere.

6.9.4 ***Thermal oxidation systems***

6.9.4.1 Thermal oxidation can be done by either consumption of the vapours according to the regulations for consumers described in this Code or in a dedicated gas combustion unit (GCU). It shall 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 shall be considered.

6.9.5 ***Compatibility***

6.9.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel shall 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 shall be compatible with each other.

6.9.6 ***Availability of systems***

6.9.6.1 The availability of the system and its supporting auxiliary services shall 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.

6.9.6.2 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges shall have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

6.10 Regulations on atmospheric control within the fuel containment system

6.10.1 A piping system shall be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition. The system shall be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

6.10.2 The system shall 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.

6.10.3 Gas sampling points shall be provided for each fuel tank to monitor the progress of atmosphere change.

6.10.4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

6.11 Regulations on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 Interbarrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers shall 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 shall be sufficient for normal consumption for at least 30 days. Shorter periods may be considered by the Administration depending on the ship's service.

6.11.2 Alternatively, the spaces referred to in 6.11.1 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 shall be provided.

6.12 Regulations on environmental control of spaces surrounding type C independent tanks

6.12.1 Spaces surrounding liquefied gas fuel tanks shall 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.

6.13 Regulations on inerting

6.13.1 Arrangements to prevent back-flow of fuel vapour into the inert gas system shall be provided as specified below.

6.13.2 To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line shall 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 shall be installed between the double block and bleed arrangement and the fuel system. These valves shall be located outside non-hazardous spaces.

6.13.3 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in 6.13.2.

6.13.4 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. shall be provided for controlling pressure in these spaces.

6.13.5 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

6.14 Regulations on inert gas production and storage on board

6.14.1 The equipment shall be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume.

6.14.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the fuel containment system.

6.14.3 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment shall be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm shall be fitted.

6.14.4 Nitrogen pipes shall only be led through well ventilated spaces. Nitrogen pipes in enclosed spaces shall:

- be fully welded;
- have only a minimum of flange connections as needed for fitting of valves; and
- be as short as possible.

7 MATERIAL AND GENERAL PIPE DESIGN

7.1 Goal

7.1.1 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.

7.2 Functional requirements

7.2.1 This chapter relates to functional requirements in 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply:

7.2.1.1 Fuel piping shall be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.

7.2.1.2 Provision shall 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.

7.2.1.3 If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid shall be fitted.

7.2.1.4 Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

7.3 Regulations for general pipe design

7.3.1 *General*

7.3.1.1 Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance shall be colour marked in accordance with a standard at least equivalent to those acceptable to the Organization.[13]

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

7.3.1.3 All pipelines or components which may be isolated in a liquid full condition shall be provided with relief valves.

7.3.1.4 Pipework, which may contain low temperature fuel, shall be thermally insulated to an extent which will minimize condensation of moisture.

7.3.1.5 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 shall only contain piping or cabling necessary for operational purposes.

7.3.2 *Wall thickness*

7.3.2.1 The minimum wall thickness shall be calculated as follows:

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

where:

t_0 = theoretical thickness

$$t_0 = PD / (2.0Ke + P) \text{ (mm)}$$

with:

P = design pressure (MPa) referred to in 7.3.3;

D = outside diameter (mm);

K = allowable stress (N/mm²) referred to in 7.3.4; and

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;

13 Refer to EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

b = allowance for bending (mm). The value of b shall 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 shall be:

$$b = D \cdot t_0 / 2.5r$$

(mm) with:

r = mean radius of the bend (mm);

c = corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping shall be increased over that required by other design regulations. This allowance shall be consistent with the expected life of the piping; and

a = negative manufacturing tolerance for thickness (%).

7.3.2.2 The absolute minimum wall thickness shall be in accordance with a standard acceptable to the Administration.

7.3.3 ***Design condition***

7.3.3.1 The greater of the following design conditions shall be used for piping, piping system and components as appropriate:[14,15]

.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; or

.2 the MARVS of the fuel tanks and fuel processing systems; or

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

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

.5 the relief valve setting on a pipeline system.

7.3.3.2 Piping, piping systems and components shall 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.

[14] Lower values of ambient temperature regarding design condition in 7.3.3.1.1 may be accepted by the Administration for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

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

7.3.4 *Allowable stress*

7.3.4.1 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 7.3.2.1 shall be the lower of the following values:

$R_m/2.7$ or $R_e/1.8$

where:

R_m = specified minimum tensile strength at room temperature (N/mm²); and

R_e = specified minimum yield stress at room temperature (N/mm²). If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

7.3.4.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by 7.3.2 or, if this is impracticable or would cause excessive local stresses, these loads shall 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.

7.3.4.3 For pipes made of materials other than steel, the allowable stress shall be considered by the Administration.

7.3.4.4 High pressure fuel piping systems shall have sufficient constructive strength. This shall 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.

7.3.4.5 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 shall be carried out for each branch of the piping system.

7.3.5 *Flexibility of piping*

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

7.3.6 *Piping fabrication and joining details*

7.3.6.1 Flanges, valves and other fittings shall comply with a standard acceptable to the Administration, taking into account the design pressure defined in 7.3.3.1. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 7.3.3.1 may be accepted.

7.3.6.2 All valves and expansion joints used in high pressure fuel piping systems shall be approved according to a standard acceptable to the Administration.

7.3.6.3 The piping system shall be joined by welding with a minimum of flange connections. Gaskets shall be protected against blow-out.

7.3.6.4 Piping fabrication and joining details shall comply with the following:

7.3.6.4.1 Direct connections

.1 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 shall 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 shall be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only 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.

.3 Screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

7.3.6.4.2 *Flanged connections*

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

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

.1 For design temperatures colder than minus 55°C, only welded neck flanges shall be used; and

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

7.3.6.4.3 *Expansion joints*

Where bellows and expansion joints are provided in accordance with 7.3.6.1 the following apply:

.1 if necessary, bellows shall be protected against icing;

.2 slip joints shall not be used except within the liquefied gas fuel storage tanks; and

.3 bellows shall normally not be arranged in enclosed spaces.

7.3.6.4.4 Other connections

Piping connections shall be joined in accordance with 7.3.6.4.1 to 7.3.6.4.3 but for other exceptional cases the Administration may consider alternative arrangements.

7.4 Regulations for materials

7.4.1 Metallic materials

7.4.1.1 Materials for fuel containment and piping systems shall comply with the minimum regulations given in the following tables:

Table 7.1: Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 7.2: 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 7.3: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below minus 55°C and down to minus 165°C.

Table 7.4: 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 7.5: Plates and sections for hull structures required by 6.4.13.1.1.2.

Table 7.1

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 TREATMENT		
◆ Carbon-manganese steel		
◆ Fully killed fine grain steel		
◆ Small additions of alloying elements by agreement with the Administration		
◆ Composition limits to be approved by the Administration		
◆ 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 ≤ 20	0
	20 < t ≤40[3]	-20

Notes

1. For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Administration.
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 shall be approved by the Administration.
4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.
5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Table 7.2

PLATES, SECTIONS AND FORGINGS [1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO MINUS 55°C
Maximum thickness 25 mm [2]

CHEMICAL COMPOSITION AND HEAT TREATMENT

- Carbon-manganese steel
- Fully killed, aluminium treated fine grain steel
- Chemical composition (ladle analysis)

C	Mn	Si	S	P
0.16% max. [3]	0.70-1.60%	0.10-0.50%	0.025% max.	0.025% max.

Optional additions: Alloys and grain refining elements may be generally in accordance with the following

Ni	Cr	Mo	Cu	Nb
0.80% max.	0.25% max.	0.08% max.	0.35% max.	0.05% max.
V				
0.10% max.				

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

Material thickness (mm)	Test temperature (°C)
25 < t ≤ 30	10°C below design temperature or -20°C whichever is lower
30 < t ≤ 35	15°C below design temperature or -20°C whichever is lower
35 < t ≤ 40	20°C below design temperature
40 < t	Temperature approved by the Administration

   The impact energy value shall 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 shall be the same as that required for the adjacent tank-shell thickness.
3. By special agreement with the Administration, 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/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance:
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 7.3 may be necessary.

Table 7.3

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 [3, 4]

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[6, 7]	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6, 7]	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered[6, 7 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 shall be subject to special consideration by the Administration.
2. The regulations for design temperatures below –165°C shall be specially agreed with the Administration.
3. For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, ~~the impact tests shall be conducted as follows:~~

~~Material thickness (mm)~~	~~Test temperature (°C)~~
~~25 < t ≤ 30~~	~~10°C below design temperature~~
~~30 < t ≤ 35~~	~~15°C below design temperature~~
~~35 < t ≤ 40~~	~~20°C below design temperature~~

The energy value shall 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 shall be specially considered.

4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
5. The chemical composition limits shall be in accordance with recognized standards.
6. Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by the Administration.
7. A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Administration.
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 the Administration.

Table 7.4

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, Normalized and tempered or quenched and tempered.[6]	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	-95	34
-165	9% nickel steel[7]. Double normalized and tempered or quenched and tempered.	-196	41
	Austenitic 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 shall be specially approved by the Administration.
2. The regulations for forgings and castings may be subject to special consideration by the Administration.
3. The regulations for design temperatures below -165°C shall be specially agreed with the Administration.
4. The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.
5. The composition limits shall be in accordance with Recognized Standards.
6. A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.
7. This chemical composition is not suitable for castings.
8. Impact tests may be omitted subject to agreement with the Administration.

Table 7.5

PLATES AND SECTIONS FOR HULL STRUCTURES REQUIRED BY 6.4.13.1.1.2								
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	x	20	25	50	20	40	50	50
down to -20	x	x	20	50	x	30	50	50
down to -30	x	x	x	40	x	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.							

Notes
'x' means steel grade not to be used.

7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks.

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

7.4.1.4 Where required the outer pipe or duct containing high pressure gas in the inner pipe shall as a minimum fulfil the material regulations for pipe materials with design temperature down to minus 55°C in table 7.4.

7.4.1.5 The outer pipe or duct around liquefied gas fuel pipes shall as a minimum fulfil the material regulations for pipe materials with design temperature down to minus 165°C in table 7.4.

8 BUNKERING

8.1 Goal

8.1.1 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.

8.2 Functional requirements

8.2.1 This chapter relates to functional requirements in 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

8.2.1.1 The piping system for transfer of fuel to the storage tank shall be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.3 Regulations for bunkering station

8.3.1 *General*

8.3.1.1 The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment.

8.3.1.2 Connections and piping shall 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.

8.3.1.3 Arrangements shall be made for safe management of any spilled fuel.

8.3.1.4 Suitable means shall 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.

8.3.1.5 The surrounding hull or deck structures shall not be exposed to unacceptable cooling, in case of leakage of fuel.

8.3.1.6 For CNG bunkering stations, low temperature steel shielding shall be considered to determine if the escape of cold jets impinging on surrounding hull structure is possible.

8.3.2 ***Ships' fuel hoses***

8.3.2.1 Liquid and vapour hoses used for fuel transfer shall be compatible with the fuel and suitable for the fuel temperature.

8.3.2.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose can be subjected to during bunkering.

8.4 Regulations for manifold

8.4.1 The bunkering manifold shall be designed to withstand the external loads during bunkering. The connections at the bunkering station shall be of dry-disconnect type equipped with additional safety dry break-away coupling/ self-sealing quick release. The couplings shall be of a standard type.

8.5 Regulations for bunkering system

8.5.1 An arrangement for purging fuel bunkering lines with inert gas shall be provided.

8.5.2 The bunkering system shall be so arranged that no gas is discharged to the atmosphere during filling of storage tanks.

8.5.3 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve shall be fitted in every bunkering line close to the connecting point. It shall be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.4 Means shall be provided for draining any fuel from the bunkering pipes upon completion of operation.

8.5.5 Bunkering lines shall be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes shall be free of gas, unless the consequences of not gas freeing is evaluated and approved.

8.5.6 In case bunkering lines are arranged with a cross-over it shall be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

8.5.7 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source shall be fitted.

8.5.8 If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with 16.7.3.7 from the trigger of the alarm to full closure of the remote operated valve required by 8.5.3 shall be adjusted.

9 FUEL SUPPLY TO CONSUMERS

9.1 Goal

The goal of this chapter is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

This chapter is related to functional requirements in 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

.1 the fuel supply system shall 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 shall 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 shall be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.3 Regulations on redundancy of fuel supply

9.3.1 For single fuel installations the fuel supply system shall 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.

9.3.2 For single fuel installations, the fuel storage shall be divided between two or more tanks. The tanks shall be located in separate compartments.

9.3.3 For type C tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

9.4 Regulations on safety functions of gas supply system

9.4.1 Fuel storage tank inlets and outlets shall be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation[16] which are not accessible shall be remotely operated. Tank valves whether accessible or not shall be automatically operated when the safety system required in 15.2.2 is activated.

9.4.2 The main gas supply line to each gas consumer or set of consumers shall 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 valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers, and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve shall automatically cut off the gas supply when activated by the safety system required in 15.2.2.

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

9.4.3 The automatic master gas fuel valve shall be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.

9.4.4 Each gas consumer shall be provided with "double block and bleed" valves arrangement. These valves shall be arranged as outlined in .1 or .2 so that when the safety system required in 15.2.2 is activated this will cause the shutoff valves that are in series to close automatically and the bleed valve to open automatically and:

.1 the two shutoff valves shall be in series in the gas fuel pipe to the gas consuming equipment. The bleed valve shall be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

.2 the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

9.4.5 The two valves shall be of the fail-to-close type, while the ventilation valve shall be fail-to-open.

9.4.6 The double block and bleed valves shall also be used for normal stop of the engine.

9.4.7 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve shall be automatically ventilated assuming reverse flow from the engine to the pipe.

9.4.8 There shall 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.

9.4.9 For single-engine installations and multi-engine installations, 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.

9.4.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations means shall be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected a valve shall be automatically shut off.[17] This valve shall be located in the gas supply line before it enters the engine-room or as close as possible to the point of entry inside the engine-room. It can be a separate valve or combined with other functions, e.g. the master valve.

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 Where fuel pipes pass through enclosed spaces in the ship, they shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically underpressure ventilated with 30 air changes per hour, and gas detection as required in 15.8 shall be provided. Other solutions providing an equivalent safety level may also be accepted by the Administration.

9.5.2 The requirement in 9.5.1 need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

[17] The shutdown shall be time delayed to prevent shutdown due to transient load variations.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 Fuel piping in gas-safe machinery spaces shall be completely enclosed by a double pipe or duct fulfilling one of the following conditions:

.1 the gas piping shall be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms shall be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system shall 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 shall be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct shall 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 fan motors shall comply with the required explosion protection in the installation area. The ventilation outlet shall be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited; or

.3 other solutions providing an equivalent safety level may also be accepted by the Administration.

9.6.2 The connecting of gas piping and ducting to the gas injection valves shall be completely covered by the ducting. The arrangement shall 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.[18]

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 The pressure in the gas fuel supply system shall not exceed 1.0 MPa.

9.7.2 The gas fuel supply lines shall have a design pressure not less than 1.0 MPa.

9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.8.1 The design pressure of the outer pipe or duct of fuel systems shall not be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

[18] If gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space, double ducting may be omitted on the air inlet pipe.

9.8.2 For high-pressure fuel piping the design pressure of the ducting shall be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure shall be taken as the critical pressure 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 = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

$k = 1.31$ for CH_4

The tangential membrane stress of a straight pipe shall not 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 shall reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports shall then be submitted.

9.8.3 Verification of the strength shall be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.8.4 For low pressure fuel piping the duct shall be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes. The duct shall be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

9.9 Regulations for compressors and pumps

9.9.1 If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration shall be of gastight type.

9.9.2 Compressors and pumps shall be suitable for their intended purpose. All equipment and machinery shall be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would 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.

9.9.3 Arrangements shall 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.

9.9.4 Compressors and pumps shall be fitted with accessories and instrumentation necessary for efficient and reliable function.

10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS

10.1 Goal

10.1.1 The goal of this chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

.1 the exhaust systems shall 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 shall 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 shall be led away from where personnel may normally be present; and

.4 all gas consumers shall have a separate exhaust system.

10.3 Regulations for internal combustion engines of piston type

10.3.1 General

10.3.1.1 The exhaust system shall be equipped with explosion relief ventilation 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 system.

10.3.1.2 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 shall be carried out and reflected in the safety concept of the engine.

10.3.1.3 Each engine other than two-stroke crosshead diesel engines shall be fitted with vent systems independent of other engines for crankcases and sumps.

10.3.1.4 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media shall be vented to a safe location in the atmosphere.

10.3.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit shall be verified.

10.3.1.6 A means shall be provided to monitor and detect poor combustion or misfiring. 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.

10.3.1.7 For engines starting on fuels covered by this Code, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve shall be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system shall be provided.

10.3.2 Regulations for dual fuel engines

10.3.2.1 In case of shutoff of the gas fuel supply, the engines shall be capable of continuous operation by oil fuel only without interruption.

10.3.2.2 An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation and vice versa with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine shall automatically change to oil fuel mode. Manual activation of gas system shutdown shall always be possible.

10.3.2.3 In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

10.3.3 Regulations for gas-only engines

In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

10.3.4 Regulations for multi-fuel engines

10.3.4.1 In case of shutoff of one fuel supply, the engines shall be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power.

10.3.4.2 An automatic system shall be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine shall automatically change to an alternative fuel mode. Manual activation shall always be possible.

	GAS ONLY		**DUAL FUEL**	**MULTI FUEL**
IGNITION MEDIUM	Spark	Pilot fuel	Pilot fuel	N/A
MAIN FUEL	Gas	Gas	Gas and/ or Oil fuel	Gas and/ or Liquid

10.4 Regulations for main and auxiliary boilers

10.4.1 Each boiler shall 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.

10.4.2 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

10.4.3 Burners shall be designed to maintain stable combustion under all firing conditions.

10.4.4 On main/propulsion boilers an automatic system shall be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

10.4.5 Gas nozzles and the burner control system shall 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 the Administration to light on gas fuel.

10.4.6 There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

10.4.7 On the fuel pipe of each gas burner a manually operated shutoff valve shall be fitted.

10.4.8 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

10.4.9 The automatic fuel changeover system required by 10.4.4 shall be monitored with alarms to ensure continuous availability.

10.4.10 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

10.4.11 Arrangements shall be made to enable the boilers purging sequence to be manually activated.

10.5 Regulations for gas turbines

10.5.1 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a safe location, away from personnel.

10.5.2 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 5.6 and 9.7, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.

10.5.3 Gas detection systems and shutdown functions shall be as outlined for ESD protected machinery spaces.

10.5.4 Ventilation for the enclosure shall be as outlined in chapter 13 for ESD protected machinery spaces, but shall in addition be arranged with full redundancy (2 x 100% capacity fans from different electrical circuits).

10.5.5 For other than single fuel gas turbines, an automatic system shall 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.

10.5.6 Means shall 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 shall be shutdown.

10.5.7 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

11 FIRE SAFETY

11.1 Goal

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.

11.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

11.3 Regulations for fire protection

11.3.1 Any space containing equipment for the fuel preparation such as pumps, compressors, heat exchangers, vaporizers and pressure vessels shall be regarded as a machinery space of category A for fire protection purposes.

11.3.2 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, shall be shielded by A-60 class divisions. The A-60 class divisions shall extend up to the underside of the deck of the navigation bridge, and any boundaries above that, including navigation bridge windows, shall have A-0 class divisions. In addition, fuel tanks shall be segregated from cargo in accordance with the requirements of the International Maritime Dangerous Goods (IMDG) Code where the fuel tanks are regarded as bulk packaging. For the purposes of the stowage and segregation requirements of the IMDG Code, a fuel tank on the open deck shall be considered a class 2.1 package.

11.3.3 The space containing fuel containment system shall be separated from the machinery spaces of category A or other rooms with high fire risks. The separation shall be done by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system shall be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. The boundary between spaces containing fuel containment systems shall be either a cofferdam of at least 900 mm or A-60 class division. For type C tanks, the fuel storage hold space may be considered as a cofferdam.

11.3.4 The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk.

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

11.3.6 The bunkering station shall be separated by A-60 class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

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

11.4 Regulations for fire main

11.4.1 The water spray system required below 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 simultaneously.

11.4.2 When the fuel storage tank(s) is located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section from the supply of water.

11.5 Regulations for water spray system

11.5.1 A water spray system shall be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck.

11.5.2 The water spray system shall also 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.

11.5.3 The system shall be designed to cover all areas as specified above with an application rate of 10 $l/min/m^2$ for the largest horizontal projected surfaces and 4 $l/min/m^2$ for vertical surfaces.

11.5.4 Stop valves shall 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.

11.5.5 The capacity of the water spray pump shall be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

11.5.6 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 shall be provided.

11.5.7 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system shall be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

11.5.8 The nozzles shall be of an approved full bore type and they shall be arranged to ensure an effective distribution of water throughout the space being protected.

11.6 Regulations for dry chemical powder fire-extinguishing system

11.6.1 A permanently installed dry chemical powder fire-extinguishing system shall be installed in the bunkering station area to cover all possible leak points. The capacity shall be at least 3.5 kg/s for a minimum of 45 s. The system shall be arranged for easy manual release from a safe location outside the protected area.

11.6.2 In addition to any other portable fire extinguishers that may be required elsewhere in IMO instruments, one portable dry powder extinguisher of at least 5 kg capacity shall be located near the bunkering station.

11.7 Regulations for fire detection and alarm system

11.7.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code shall 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.

11.7.2 Smoke detectors alone shall not be considered sufficient for rapid detection of a fire.

12 EXPLOSION PREVENTION

12.1 Goal

The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.

12.2 Functional requirements

This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:

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

.1 reducing number of sources of ignition; and

.2 reducing the probability of formation of ignitable mixtures.

12.3 Regulations – General

12.3.1 Hazardous areas on open deck and other spaces not addressed in this chapter shall be decided based on a recognized standard.[19] The electrical equipment fitted within hazardous areas shall be according to the same standard.

12.3.2 Electrical equipment and wiring shall in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard.[20]

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

[20] Refer to IEC standard 60092-502: IEC 60092-502:1999 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.

12.3.3 Electrical equipment fitted in an ESD-protected machinery space shall fulfil the following:

.1 in addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans shall 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 shall be automatically disconnected, if gas concentrations above 40% LEL is detected by two detectors in the space containing gas-fuelled consumers.

12.4 Regulations on area classification

12.4.1 Area 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 be operated safely in these areas.

12.4.2 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.[21] See also 12.5 below.

12.4.3 Ventilation ducts shall have the same area classification as the ventilated space.

12.5 Hazardous area zones

12.5.1 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.

12.5.2 Hazardous area zone 1[22]

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces[23] and interbarrier spaces;

.2 fuel preparation room arranged with ventilation according to 13.6;

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet,[24] bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room 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;

21 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 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

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

[23] Fuel storage hold spaces for type C tanks are normally not considered as zone 1.

[24] 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.

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts 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 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.

12.5.3 Hazardous area zone 2[25]

12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

12.5.3.2 Space containing bolted hatch to tank connection space.

13 VENTILATION

13.1 Goal

The goal of this chapter is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.

13.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

13.3 Regulations – General

13.3.1 Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces. The ventilation shall function at all temperatures and environmental conditions the ship will be operating in.

13.3.2 Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

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

13.3.3 Design of ventilation fans serving spaces containing gas sources shall fulfil the following:

.1 Ventilation fans shall not 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, shall 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 In no case shall the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.

13.3.4 Ventilation systems required to avoid any gas accumulation shall consist of independent fans, each of sufficient capacity, unless otherwise specified in this Code.

13.3.5 Air inlets for hazardous enclosed spaces shall be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct shall be gas-tight and have over-pressure relative to this space.

13.3.6 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

13.3.7 Air outlets from hazardous enclosed spaces shall 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.

13.3.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

13.3.9 Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation shall 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 shall 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 shall be monitored and in the event of failure of the overpressure ventilation:

  .1 an audible and visual alarm shall 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[26] shall be required.

13.3.10 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an airlock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space shall be monitored and in the event of failure of the extraction ventilation:

.1 an audible and visual alarm shall 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 in the non-hazardous space shall be required.

13.4 Regulations for tank connection space

13.4.1 The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment.

13.4.2 Approved automatic fail-safe fire dampers shall be fitted in the ventilation trunk for the tank connection space.

13.5 Regulations for machinery spaces

13.5.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems.

26 Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

13.5.2 ESD protected machinery spaces shall have ventilation with a capacity of at least 30 air changes per hour. The ventilation system shall ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby 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.

13.5.3 For ESD protected machinery spaces the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard acceptable to the Organization.[27]

13.5.4 The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms shall 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.

13.6 Regulations for fuel preparation room

13.6.1 Fuel preparation rooms, shall be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

13.6.2 The number and power of the ventilation fans shall 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.

13.6.3 Ventilation systems for fuel preparation rooms, shall be in operation when pumps or compressors are working.

13.7 Regulations for bunkering station

Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1.

13.8 Regulations for ducts and double pipes

13.8.1 Ducts and double pipes containing fuel piping shall 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 9.6.1.1.

13.8.2 The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms shall be independent of all other ventilation systems.

13.8.3 The ventilation inlet for the double wall piping or duct shall always be located in a non-hazardous area away from ignition sources. The inlet opening shall be fitted with a suitable wire mesh guard and protected from ingress of water.

13.8.4 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 shall be calculated for the duct with fuel pipes and other components installed.

27 Refer to IEC 60079-10-1.

14 ELECTRICAL INSTALLATIONS

14.1 Goal

The goal of this chapter is to provide for electrical installations that minimizes the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, shall 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.

14.3 Regulations – General

14.3.1 Electrical installations shall be in compliance with a standard at least equivalent to those acceptable to the Organization.[28]

14.3.2 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

14.3.3 Where electrical equipment is installed in hazardous areas as provided in 14.3.2 it shall be selected, installed and maintained in accordance with standards at least equivalent to those acceptable to the Organization.[29]

Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.

14.3.4 Failure modes and effects of single failure for electrical generation and distribution systems in 14.2 shall be analysed and documented to be at least equivalent to those acceptable to the Organization.[30]

14.3.5 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be located in a non-hazardous area.

14.3.6 The installation on board of the electrical equipment units shall be such as to ensure the safe bonding to the hull of the units themselves.

14.3.7 Arrangements shall 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 shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

14.3.8 Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

28 Refer to IEC 60092 series standards, as applicable.

29 Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.

30 Refer to IEC 60812.

14.3.9 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 shall be de-energized upon loss of overpressure in the space.

14.3.10 Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, shall be of a certified safe type.

15 CONTROL, MONITORING AND SAFETY SYSTEMS

15.1 Goal

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.

15.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

.1 the control, monitoring and safety systems of the gas-fuelled installation shall be so arranged that the remaining power for propulsion and power generation is in accordance with 9.3.1 in the event of single failure;

.2 a gas safety system shall be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention;

.3 for ESD protected machinery configurations the safety system shall shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

.4 the safety functions shall 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;

.5 the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

.6 where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent gas control and gas safety systems.

15.3 Regulations – General

15.3.1 Suitable instrumentation devices shall 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.

15.3.2 A bilge well in each tank connection space of an independent liquefied gas storage tank shall be provided with both a level indicator and a temperature sensor. Alarm shall be given at high level in the bilge well. Low temperature indication shall activate the safety system.

15.3.3 For tanks not permanently installed in the ship a monitoring system shall be provided as for permanently installed tanks.

15.4 Regulations for bunkering and liquefied gas fuel tank monitoring

15.4.1 Level indicators for liquefied gas fuel tanks

.1 Each liquefied gas fuel tank shall 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) shall 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 shall 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;

15.4.2 Overflow control

.1 Each liquefied gas fuel tank shall 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 operating independently of the high liquid level alarm shall 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.

.3 The position of the sensors in the liquefied gas fuel tank shall 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 shall 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, shall be capable of being functionally tested. Systems shall be tested prior to fuel operation in accordance with 18.4.3.

.5 Where arrangements are provided for overriding the overflow control system, they shall 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.

15.4.3 The vapour space of each liquefied gas fuel tank shall 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.

15.4.4 The pressure indicators shall be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.

15.4.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms shall be activated before the set pressures of the safety valves are reached.

15.4.6 Each fuel pump discharge line and each liquid and vapour fuel manifold shall be provided with at least one local pressure indicator.

15.4.7 Local-reading manifold pressure indicator shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

15.4.8 Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indicator.

15.4.9 At least one of the pressure indicators provided shall be capable of indicating throughout the operating pressure range.

15.4.10 For submerged fuel-pump motors and their supply cables, arrangements shall 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 shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

15.4.11 Except for independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank shall be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.

15.5 Regulations for bunkering control

15.5.1 Control of the bunkering shall be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by 15.4.11, and tank level shall be monitored. Remotely controlled valves required by 8.5.3 and 11.5.7 shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location.

15.5.2 If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm shall be provided at the bunkering control location, see also 15.8.

15.5.3 If gas is detected in the ducting around the bunkering lines an audible and visual alarm and emergency shutdown shall be provided at the bunkering control location.

15.6 Regulations for gas compressor monitoring

15.6.1 Gas compressors shall be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms shall include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

15.6.2 Temperature monitoring for the bulkhead shaft glands and bearings shall be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

15.7 Regulations for gas engine monitoring

In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators shall 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.

15.8 Regulations for gas detection

15.8.1 Permanently installed gas detectors shall be fitted in:

.1 the tank connection spaces;

.2 all ducts around fuel pipes;

.3 machinery spaces containing gas piping, gas equipment or gas consumers;

.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 or at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2.

15.8.2 In each ESD-protected machinery space, redundant gas detection systems shall be provided.

15.8.3 The number of detectors in each space shall be considered taking into account the size, layout and ventilation of the space.

15.8.4 The detection equipment shall be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test shall be used to find the best arrangement.

15.8.5 Gas detection equipment shall be designed, installed and tested in accordance with a recognized standard.[31]

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

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

15.8.7 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 shall be activated at 60% of LEL at two detectors (see footnote 1 in table 1).

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

15.8.9 Gas detection required by this section shall be continuous without delay.

15.9 Regulations for fire detection

Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in table 1 below.

15.10 Regulations for ventilation

15.10.1 Any loss of the required ventilating capacity shall give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre.

15.10.2 For ESD protected machinery spaces the safety system shall be activated upon loss of ventilation in engine-room.

15.11 Regulations on safety functions of fuel supply systems

15.11.1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply shall not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect shall be placed at the operating station for the shutoff valves in the fuel supply lines.

15.11.2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply shall not be operated until the leak has been found and dealt with. Instructions to this effect shall be placed in a prominent position in the machinery space.

15.11.3 A caution placard or signboard shall be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, shall not be done when the engine(s) is running on gas.

15.11.4 Compressors, pumps and fuel supply shall 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 shall also be arranged for manual local emergency stop.

Table 1: Monitoring of gas supply system to engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection in tank connection space at 20% LEL	X			
Gas detection on two detectors[1)] in tank connection space at 40% LEL	X	X		
Fire detection in fuel storage hold space	X			
Fire detection in ventilation trunk for fuel containment system below deck	X			
Bilge well high level in tank connection space	X			
Bilge well low temperature in tank connection space	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X[2)]		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X[2)]		
Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection on two detectors[1)] in duct inside machinery space containing gas-fuelled engines at 60% LEL	X		X[3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in ESD protected machinery space containing gas-fuelled engines at 40% LEL	X		X	It shall also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X[2)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5)]	X		X[3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	X		X	
Fire detection in machinery space containing gas-fuelled engines	X			
Abnormal gas pressure in gas supply pipe	X			
Failure of valve control actuating medium	X		X[4)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[4)]	

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Manually activated emergency shutdown of engine	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.

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 shall 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 shall close.

4) Only double block and bleed valves to close.

5) If the duct is protected by inert gas (see 9.6.1.1) then loss of inert gas overpressure shall lead to the same actions as given in this table.

6) Valves referred to in 9.4.1.

ANNEX

STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF FUEL CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

1 GENERAL

1.1 The purpose of this standard is to provide procedures and relevant design parameters of limit state design of fuel containment systems of a novel configuration in accordance with section 6.4.16.

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

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.

1.4 Section 6.4.1 through to section 6.4.14 shall be complied with as applicable depending on the fuel containment system concept.

2 DESIGN FORMAT

2.1 The design format in this standard is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, L_d, do not exceed design resistances, R_d, for any of the considered failure modes in any scenario:

$$L_d \leq R_d$$

A design load F_{dk} is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where:

γ_f is load factor; and

F_k is the characteristic load as specified in section 6.4.9 through to section 6.4.12.

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:

$$L_d = q\left(F_{d1}, F_{d2}, ..., F_{dN}\right)$$

where q denotes the functional relationship between load and load effect determined by structural analyses. The design resistance R_d is determined as follows:

$$R_d = \frac{R_k}{\gamma_R \cdot \gamma_C}$$

where:

R_k is the characteristic resistance. In case of materials covered by chapter 7, 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 is the resistance factor, defined as $\gamma_R = \gamma_m \cdot \gamma_s$;

γ_m is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);

γ_s is 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 is the consequence class factor, which accounts for the potential results of failure with regard to release of fuel and possible human injury.

2.2 Fuel containment design shall take into account potential failure consequences. Consequence classes are defined in table 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.

Table 1: Consequence classes

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.

3 REQUIRED ANALYSES

3.1 Three-dimensional finite element analyses shall 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 shall be identified to avoid unexpected failures. Hydrodynamic analyses shall 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.

3.2 Buckling strength analyses of fuel tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately 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.

3.3 Fatigue and crack propagation analysis shall be carried out in accordance with paragraph 5.1 of this standard.

4 ULTIMATE LIMIT STATES

4.1 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 shall 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).

4.2 Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in table 2 shall be used for the assessment of the ultimate limit states.

Table 2: Partial load factors

Load combination	Permanent loads	Functional loads	Environmental loads
'*a*'	1.1	1.1	0.7
'*b*'	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination '*a*' are relevant for the normally well-controlled and/or specified loads applicable to fuel containment systems such as vapour pressure, fuel weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.

4.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Administration.

4.4 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 shall 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 the Administration. The risk analysis shall 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 the Administration, for example, for ships carrying more hazardous or higher pressure fuel. The consequence class factor shall in any case not be less than 1.0.

4.5 The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the fuel containment systems as described in sections 6.4.2.1 to 6.4.2.5. This may be carried out by calibrating the factors against known successful designs.

4.6 The material factor γ_m shall in general 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 6, the material factor γ_m may be taken as:

1.1 when the characteristic mechanical properties specified by the Administration typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or

1.0 when the characteristic mechanical properties specified by the Administration represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.7 The partial resistance factors γ_{si} shall in general 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.

4.7.1 For design against excessive plastic deformation using the limit state criteria given in paragraph 4.8 of this standard, the partial resistance factors γ_{si} shall be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = Min\left(\frac{R_m}{R_e} \cdot \frac{B}{A}; 1.0\right)$$

$$\kappa_2 = Min\left(\frac{R_m}{R_e} \cdot \frac{D}{C}; 1.0\right)$$

Factors A, B, C and D are defined in 6.4.15.2.3.1. R_m and R_e are defined in 6.4.12.1.1.3.

The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

4.8 Design against excessive plastic deformation

4.8.1 Stress acceptance criteria given below refer to elastic stress analyses.

4.8.2 Parts of fuel containment systems where loads are primarily carried by membrane response in the structure shall satisfy the following limit state criteria:

$$_{m} \leq f$$
$$\sigma_L \leq 1.5f$$
$$\sigma_b \leq 1.5F$$
$$\sigma_L + \sigma_b \leq 1.5F$$
$$\sigma_m + \sigma_b \leq 1.5F$$
$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$
$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

where:

$_m$ = equivalent primary general membrane stress
$_L$ = equivalent primary local membrane stress
$_b$ = equivalent primary bending stress
$_g$ = equivalent secondary stress

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

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

Guidance Note:

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

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}$$

4.8.3 Parts of fuel containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

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

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

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

Note 1: The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

Note 2: The coefficient, 1.25, may be modified by the Administration considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

where:

σ_{ms}
σ_{bp}
σ_{bs}
σ_{bt}
σ_g

= equivalent section membrane stress in primary structure

= equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure

= section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure

= section bending stress in tertiary structure

= 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}, are defined in 4.8.4.
and σ_{bt}

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component ($\sigma_x, \sigma_y, \tau_{xy}$), and subsequently the equivalent stress shall be calculated based on the resulting stress components.

Skin plates shall be designed in accordance with the requirements of the Administration. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.

4.8.4 Section stress categories

Normal stress is the component of stress normal to the plane of reference.

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 4.8.2 of this standard.

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 1.

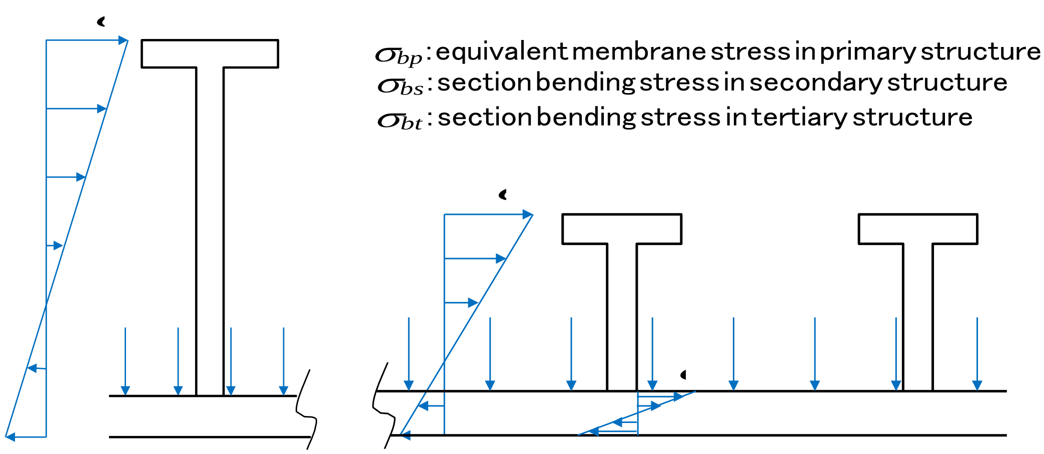


Figure 1: Definition of the three categories of section stress (Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.9 The same factors γ_C, γ_m, γ_{si} shall be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case the overall level of safety shall not be less than given by these factors.

5 FATIGUE LIMIT STATES

5.1 Fatigue design condition as described in 6.4.12.2 shall be complied with as applicable depending on the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under 6.4.16 and this standard.

5.2 The load factors for FLS shall be taken as 1.0 for all load categories.

5.3 Consequence class factor γ_C and resistance factor γ_R shall be taken as 1.0.

5.4 Fatigue damage shall be calculated as described in 6.4.12.2.2 to 6.4.12.2.2.5. The calculated cumulative fatigue damage ratio for the fuel containment systems shall be less than or equal to the values given in table 3.

Table 3: Maximum allowable cumulative fatigue damage ratio

	Consequence class		
C_W	Low	Medium	High
	1.0	0.5	0.5*

Note*: Lower value shall be used in accordance with 6.4.12.2.7 to 6.4.12.2.9, depending on the detectability of defect or crack, etc.

5.5 Lower values may be fixed by the Administration.

5.6 Crack propagation analyses are required in accordance with 6.4.12.2.6 to 6.4.12.2.9. The analysis shall be carried out in accordance with methods laid down in a standard recognized by the Administration.

6 ACCIDENT LIMIT STATES

6.1 Accident design condition as described in 6.4.12.3 shall be complied with as applicable, depending on the fuel containment system concept.

6.2 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.

6.3 The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.4 Loads mentioned in 6.4.9.3.3.8 and 6.4.9.5 need not be combined with each other or with environmental loads, as defined in 6.4.9.4.

6.5 Resistance factor γ_R shall in general be taken as 1.0.

6.6 Consequence class factors γ_C shall in general be taken as defined in paragraph 4.4 of this standard, but may be relaxed considering the nature of the accident scenario.

6.7 The characteristic resistance R_k shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.8 Additional relevant accident scenarios shall be determined based on a risk analysis.

7 TESTING

7.1 Fuel containment systems designed according to this standard shall be tested to the same extent as described in 16.2, as applicable depending on the fuel containment system concept.

PART B-1

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

16 MANUFACTURE, WORKMANSHIP AND TESTING

16.1 General

16.1.1 The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the regulations given in this Code.

16.1.2 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat treated condition, in accordance with the applicable tables of chapter 7, and the weld properties shall be determined in the heat treated condition in accordance with 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Administration.

16.2 General test regulations and specifications

16.2.1 ***Tensile test***

16.2.1.1 Tensile testing shall be carried out in accordance with recognized standards.

16.2.1.2 Tensile strength, yield stress and elongation shall be to the satisfaction of the Administration. For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.

16.2.2 ***Toughness test***

16.2.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests unless otherwise specified by the Administration. 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 shall be in accordance with recognized standards. The testing and regulations for specimens smaller than 5.0 mm in size shall be in accordance with recognized standards. Minimum average values for sub-sized specimens shall be:

Charpy V-notch specimen size (mm)	Minimum average energy of three specimens
10 x 10	KV
10 x 7.5	5/6 KV
10 x 5.0	2/3 KV

where:

KV = the energy values (J) specified in tables 7.1 to 7.4.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

16.2.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall 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 16.1.

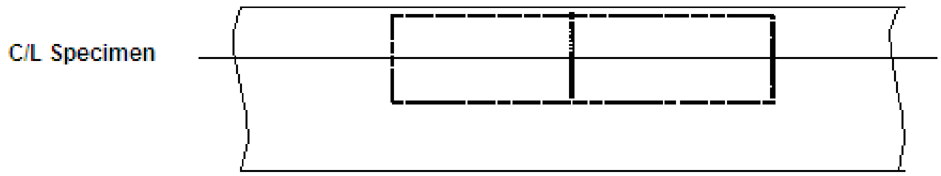


Figure 16.1 – Orientation of base metal test specimen

16.2.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall 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 shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the following locations, as shown in figure 16.2, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.

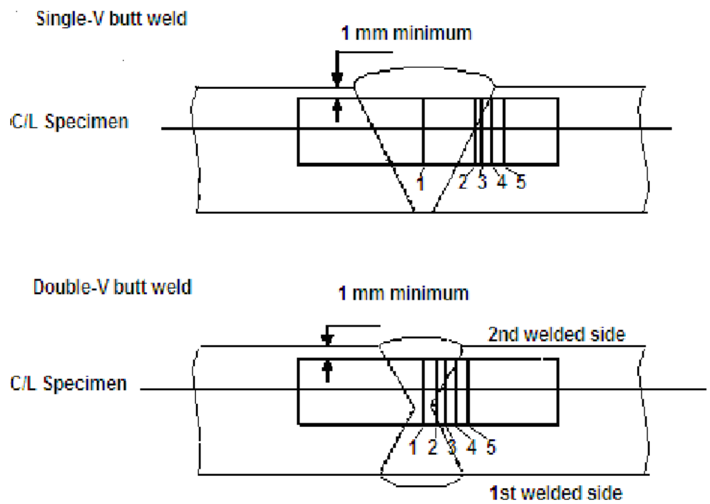


Figure 16.2 – Orientation of weld test specimen

Notch locations in figure 16.2:

.1 centreline of the weld;

.2 on fusion line;

.3 in heat-affected zone (HAZ), 1 mm from fusion line;

.4 in HAZ, 3 mm from fusion line; and

.5 in HAZ, 5 mm from fusion line.

16.2.2.4 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.

16.2.3 ***Bend test***

16.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards.

16.2.3.2 The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Administration. 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.

16.2.4 ***Section observation and other testing***

Macrosection, microsection observations and hardness tests may also be required by the Administration, and they shall be carried out in accordance with recognized standards, where required.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

16.3.1 ***General***

This section shall 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 the Administration, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

16.3.2 ***Welding consumables***

Consumables intended for welding of fuel tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information.

16.3.3 ***Welding procedure tests for fuel tanks and process pressure vessels***

16.3.3.1 Welding procedure tests for fuel tanks and process pressure vessels are required for all butt welds.

16.3.3.2 The test assemblies shall be representative of:

.1 each base material;

.2 each type of consumable and welding process; and

.3 each welding position.

16.3.3.3 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.

16.3.3.4 The following welding procedure tests for fuel tanks and process pressure vessels shall be done in accordance with 16.2 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 16.2:

  .1 centreline of the welds;

  .2 fusion line;

  .3 1 mm from the fusion line;

  .4 3 mm from the fusion line; and

  .5 5 mm from the fusion line;

.5 macrosection, microsection and hardness survey may also be required.

16.3.3.5 Each test shall 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 shall be made to 6.4.12.1.1.3 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 shall be recorded for information;

.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

.3 Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal regulations for sub-size specimens and single energy values shall be in accordance with 16.2.2. The results of fusion line and heat affected zone impact tests shall 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) shall be in accordance with 16.2.2. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards.

16.3.3.6 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.

16.3.4 *Welding procedure tests for piping*

Welding procedure tests for piping shall be carried out and shall be similar to those detailed for fuel tanks in 16.3.3.

16.3.5 *Production weld tests*

16.3.5.1 For all fuel tanks and process pressure vessels except membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Administration. Tests, other than those specified in 16.3.5.2 to 16.3.5.5 may be required for fuel tanks or secondary barriers.

16.3.5.2 The production tests for types A and B independent tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall 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 shall be in the centre of the weld.

16.3.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 16.3.5.2. Tensile tests shall meet regulation 16.3.3.5.

16.3.5.4 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual (QM).

16.3.5.5 The test regulations for membrane tanks are the same as the applicable test regulations listed in 16.3.3.

16.3.6 *Non-destructive testing*

16.3.6.1 All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall 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 shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.

16.3.6.2 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 shall 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 16.3.6.1.

16.3.6.3 In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods as considered necessary.

16.3.6.4 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:

.1 Total non-destructive testing referred to in 6.4.15.3.2.1.3

Radiographic testing:

.1 all butt welds over their full length.

Non-destructive testing for surface crack detection:

.2 all welds over 10% of their length;

.3 reinforcement rings around holes, nozzles, etc. over their full length.

As an alternative, ultrasonic testing, as described in 16.3.6.1, may be accepted as a partial substitute for the radiographic testing. In addition, the Administration may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

.2 Partial non-destructive testing referred to in 6.4.15.3.2.1.3:

Radiographic testing:

.1 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:

.2 reinforcement rings around holes, nozzles, etc. over their full length.

Ultrasonic testing:

.3 as may be required by the Administration in each instance.

16.3.6.5 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM).

16.3.6.6 Inspection of piping shall be carried out in accordance with the regulations of chapter 7.

16.3.6.7 The secondary barrier shall 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 shall be tested by radiographic testing.

16.4 Other regulations for construction in metallic materials

16.4.1 *General*

Inspection and non-destructive testing of welds shall be in accordance with regulations in 16.3.5 and 16.3.6. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.

16.4.2 *Independent tank*

For type C tanks and type B tanks primarily constructed of bodies of revolution the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in 6.4.15.2.3.1 and 6.4.15.3.3.2.

16.4.3 *Secondary barriers*

During construction the regulations for testing and inspection of secondary barriers shall be approved or accepted by the Administration (see also 6.4.4.5 and 6.4.4.6).

16.4.4 *Membrane tanks*

The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.

16.5 Testing

16.5.1 *Testing and inspections during construction*

16.5.1.1 All liquefied gas fuel tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 16.5.2 to 16.5.5, as applicable for the tank type.

16.5.1.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 16.5.1.1.

16.5.1.3 The gas tightness of the fuel containment system with reference to 6.3.3 shall be tested.

16.5.1.4 Regulations with respect to inspection of secondary barriers shall be decided by the Administration in each case, taking into account the accessibility of the barrier (see also 6.4.4).

16.5.1.5 The Administration may require that for ships fitted with novel type B independent tanks, or tanks designed according to 6.4.16 at least one prototype tank and its support shall be instrumented with strain gauges or other suitable equipment to confirm stress levels during the testing required in 16.5.1.1. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

16.5.1.6 The overall performance of the fuel containment system shall 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 the Administration. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained on board and be available to the Administration.

16.5.1.7 The fuel containment system shall 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 shall be carried out in accordance with the requirements of the Administration.

16.5.1.8 Heating arrangements, if fitted in accordance with 6.4.13.1.1.3 and 6.4.13.1.1.4, shall be tested for required heat output and heat distribution.

16.5.2 *Type A independent tanks*

All type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test shall 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 shall 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.

16.5.3 *Type B independent tanks*

Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing as follows:

.1 The test shall be performed as required in 16.5.2 for type A independent tanks.

.2 In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not 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 test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment.

16.5.4 *Type C independent tanks and other pressure vessels*

16.5.4.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 P_0. In no case during the pressure test shall the calculated primary membrane stress at any point 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 test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

16.5.4.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

16.5.4.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

16.5.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 16.5.4.1 to 16.5.4.3.

16.5.4.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, regulation in 16.5.4.1 shall be fully complied with.

16.5.4.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in 16.5.4.1 or 16.5.4.4 as applicable.

16.5.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks shall be considered on an individual case basis. Such testing shall only 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.

16.5.5 ***Membrane tanks***

16.5.5.1 *Design development testing*

16.5.5.1.1 The design development testing required in 6.4.15.4.1.2 shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads at all filling levels. This will culminate in the construction of a prototype scaled model of the complete liquefied gas fuel containment system. Testing conditions considered in the analytical and physical model shall 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 6.4.4 may be based on the results of testing carried out on the prototype scaled model.

16.5.5.1.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

16.5.5.2 *Testing*

.1 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, shall be hydrostatically tested.

.2 All hold structures supporting the membrane shall be tested for tightness before installation of the liquefied gas fuel containment system.

.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

16.6 Welding, post-weld heat treatment and non-destructive testing

16.6.1 General

Welding shall be carried out in accordance with 16.3.

16.6.2 Post-weld heat treatment

Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Administration 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.

16.6.3 Non-destructive testing

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 the regulations in this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with;

  .1 design temperatures colder than minus 10°C; or

  .2 design pressure greater than 1.0 MPa; or

  .3 gas supply pipes in ESD protected machinery spaces; or

  .4 inside diameters of more than 75 mm; or

  .5 wall thicknesses greater than 10 mm.

.2 When such butt welded joints of piping sections are made by automatic welding procedures approved by the Administration, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed the extent of examination shall be increased to 100% and shall 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.

.3 The radiographic or ultrasonic inspection regulation may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.

.4 For other butt-welded joints of pipes not covered by 16.6.3.1 and 16.6.3.3, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

16.7 Testing regulations

16.7.1 Type testing of piping components

Valves

Each type of piping component intended to be used at a working temperature below minus 55˚C shall be subject to the following type tests:

.1 Each size and type of valve shall 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 shall be to the requirements of the Administration During the testing satisfactory operation of the valve shall be verified.

.2 The flow or capacity shall be certified to a recognized standard for each size and type of valve.

.3 Pressurized components shall be pressure tested to at least 1.5 times the design pressure.

.4 For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard at least equivalent to those acceptable to the Organization.[32]

16.7.2 Expansion bellows

The following type tests shall be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable in 7.3.6.4.3.1.3 and where required by the Administration, on those installed within the fuel tanks:

.1 Elements of the bellows, not pre-compressed, but axially restrained shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.

.2 A pressure test shall 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.

.3 A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall 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.

.4 A cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 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.

16.7.3 System testing regulations

16.7.3.1 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 the Administration.

16.7.3.2 After assembly, all fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure shall 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 shall be tested to at least 1.5 times the design pressure.

[32] Refer to the recommendations by the International Organization for Standardization, in particular publications:

ISO 19921:2005, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods*

ISO 19922:2005, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench*

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

16.7.3.4 In double wall fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture.

16.7.3.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, shall be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Administration.

16.7.3.6 Emergency shutdown valves in liquefied gas piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

16.7.3.7 The closing time of the valve referred to in 8.5.8 and 15.4.2.2 (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than:

$$\frac{3600U}{BR}$$ *(second)*

where:

U = ullage volume at operating signal level (m^3);

BR = maximum bunkering rate agreed between ship and shore facility (m^3/h); or

5 seconds, whichever is the least.

The bunkering rate shall 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.

PART C-1

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

17 DRILLS AND EMERGENCY EXERCISES

Drills and emergency exercises on board shall be conducted at regular intervals. Such

gas-related exercises could include for example:

.1 tabletop exercise;

.2 review of fueling procedures based in the fuel handling manual required by 18.2.3;

.3 responses to potential contingences;

.4 tests of equipment intended for contingency response; and

.5 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.

Gas related exercises may be incorporated into periodical drills required by SOLAS.

The response and safety system for hazards and accident control shall be reviewed and tested.

18 OPERATION

18.1 Goal

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.

18.2 Functional requirements

This chapter relates to the functional requirements in 3.2.1 to 3.2.3, 3.2.9, 3.2.11, 3.2.15, 3.2.16 and 3.2.17. In particular the following apply:

.1 a copy of this Code, or national regulations incorporating the provisions of this Code, shall be on board every ship covered by this Code;

.2 maintenance procedures and information for all gas related installations shall be available on board;

.3 the ship shall 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

.4 the ship shall be provided with suitable emergency procedures.

18.3 Regulations for maintenance

18.3.1 Maintenance and repair procedures shall include considerations with respect to the tank location and adjacent spaces (see chapter 5).

18.3.2 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 6.4.1.8.

18.3.3 The procedures and information shall 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 shall be performed in accordance with a recognized standard.[33]

18.4 Regulations for bunkering operations

18.4.1 Responsibilities

18.4.1.1 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) shall:

.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.

18.4.1.2 Upon completion of bunkering operations the ship PIC shall receive and sign a Bunker Delivery Note for the fuel delivered, containing at least the information specified in the annex to part C-1, completed and signed by the bunkering source PIC.

18.4.2 Overview of control, automation and safety systems

18.4.2.1 The fuel handling manual required by 18.2.3 shall 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;

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

.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.

18.4.2.2 A fuel system schematic/piping and instrumentation diagram (P&ID) shall be reproduced and permanently mounted in the ship's bunker control station and at the bunker station.

18.4.3 Pre-bunkering verification

18.4.3.1 Prior to conducting bunkering operations, pre-bunkering verification including, but not limited to the following, shall 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.

18.4.3.2 Documentation of successful verification shall be indicated by the mutually agreed and executed bunkering safety checklist signed by both PIC's.

18.4.4 Ship bunkering source communications

18.4.4.1 Communications shall 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 shall stop and not resume until communications are restored.

18.4.4.2 Communication devices used in bunkering shall comply with recognized standards for such devices acceptable to the Administration.

18.4.4.3 PIC's shall have direct and immediate communication with all personnel involved in the bunkering operation.

18.4.4.4 The ship shore link (SSL) or equivalent means to a bunkering source provided for automatic ESD communications, shall be compatible with the receiving ship and the delivering facility ESD system.[34]

18.4.5 Electrical bonding

Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering shall be electrically continuous, suitably insulated and shall provide a level of safety compliant with recognized standards.[35]

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

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

18.4.6 Conditions for transfer

18.4.6.1 Warning signs shall be posted at the access points to the bunkering area listing fire safety precautions during fuel transfer.

18.4.6.2 During the transfer operation, personnel in the bunkering manifold area shall be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations shall wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer shall be cause to stop operations and transfer shall not be resumed until all required conditions are met.

18.4.6.3 Where bunkering is to take place via the installation of portable tanks, the procedure shall provide an equivalent level of safety as integrated fuel tanks and systems. Portable tanks shall be filled prior to loading on board the ship and shall be properly secured prior to connection to the fuel system.

18.4.6.4 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 shall 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.

18.5 Regulations for enclosed space entry

18.5.1 Under normal operational circumstances, personnel shall not 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.[36]

18.5.2 Personnel entering any space designated as a hazardous area shall not introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

18.6 Regulations for inerting and purging of fuel systems

18.6.1 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.

18.6.2 Procedures for inerting and purging of fuel systems shall 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.

18.7 Regulations for hot work on or near fuel systems

18.7.1 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 shall only be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained.

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

ANNEX

LNG-BUNKER DELIVERY NOTE* LNG AS FUEL FOR

SHIP NAME:______________________ IMO NO.:________

Date of delivery:

1. LNG-Properties

Methane number **	--	
Lower calorific (heating) value	MJ/kg	
Higher calorific (heating) value	MJ/kg	
Wobbe Indices Ws / Wi	MJ/m³	
Density	kg/m³	
Pressure	MPa (abs)	
LNG temperature delivered	°C	
LNG temperature in storage tank(s)	°C	
Pressure in storage tank(s)	MPa (abs)	

2. LNG-Composition

Methane, CH_4	% (kg/kg)
Ethane, C_2H_6	% (kg/kg)
Propane, C_3H_8	% (kg/kg)
Isobutane, i C_4H_{10}	% (kg/kg)
N-Butane, n C_4H_{10}	% (kg/kg)
Pentane, C_5H_{12}	% (kg/kg)
Hexane; C_6H_{14}	% (kg/kg)
Heptane; C_7H_{16}	% (kg/kg)
Nitrogen, N_2	% (kg/kg)
Sulphur, S	% (kg/kg)
negligible<5ppm hydrogen sulphide, hydrogen, ammonia, chlorine, fluorine, water	

3. Net Total delivered:_____________t,___________________MJ______________m³
Net Liquid delivery:______________GJ

4. Signature(s):

Supplier Company Name, contact details:________________________

Signature:__________________Place/Port_____________date:___________________

Receiver:____________________________

* The LNG properties and composition allow the operator to act in accordance with the known properties of the gas and any operational limitations linked to that.

** Preferably above 70 and referring to the used methane number calculation method in DIN EN 16726. This does not necessarily reflect the methane number that goes into the engine.

19 TRAINING

19.1 Goal

The goal of this chapter is to ensure that seafarers on board ships to which this Code applies are adequately qualified, trained and experienced.

19.2 Functional requirements

Companies shall ensure that seafarers on board ships using gases or other low-flashpoint fuels shall have completed training to attain the abilities that are appropriate to the capacity to be filled and duties and responsibilities to be taken up, taking into account the provisions given in the STCW Convention and Code, as amended.

ANNEX 11

RESOLUTION MSC.285(86)
(adopted on 1 June 2009)

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Organization concerning the functions of the Committee,

NOTING that the International Convention for the Safety of Life at Sea, 1974 currently does not have any provisions for use of gas as fuel on ships other than gas carriers,

RECOGNIZING a need for the development of a code for gas-fuelled ships,

ACKNOWLEDGING that, in the interim, there is an urgent need to provide guidance to the Administrations on the gas-fuelled engine installations in ships,

HAVING CONSIDERED the Interim Guidelines prepared by the Sub-Committee on Bulk Liquids and Gases at its thirteenth session,

1. ADOPTS the Interim Guidelines on safety for natural gas-fuelled engine installations in ships, the text of which is set out in the Annex to the present resolution;

2. INVITES Governments to apply the Interim Guidelines to gas-fuelled ships other than those covered by the IGC Code;

3. URGES Member Governments and the industry to submit information, observations, comments and recommendations based on the practical experience gained through the application of these Interim Guidelines and submit relevant safety analysis on gas-fuelled installations;

4. AGREES to continue the work on the development of the International Code of Safety for Gas-fuelled Ships (IGF Code).

ANNEX

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

Index

2.l0.3 Machinery spaces containing gas-fuelled engines

2.l0.4 Pump and compressor rooms

CHAPTER 3 - FIRE SAFETY

CHAPTER 4 - ELECTRICAL SYSTEMS

CHAPTER 5 - CONTROL, MONITORING AND SAFETY SYSTEMS

CHAPTER 6 - COMPRESSORS AND GAS ENGINES

CHAPTER 7 - MANUFACTURE, WORKMANSHIP AND TESTING

CHAPTER 8 - OPERATIONAL AND TRAINING REQUIREMENTS

PREAMBLE

1 These Interim Guidelines have been developed to provide an international standard for ships, other than vessels covered by the IGC Code, with natural gas-fuelled engine installations.

2 The goal of these Interim Guidelines is to provide criteria for the arrangement and installation of machinery for propulsion and auxiliary purposes, using natural gas as fuel, which will have an equivalent level of integrity in terms of safety, reliability and dependability as that which can be achieved with a new and comparable conventional oil-fuelled main and auxiliary machinery.

3 To achieve this goal, the functional requirements described below are embodied in the relevant parts of these Interim Guidelines:

.1 Minimize hazardous areas as far as is practicable to reduce the potential risks that might affect the safety of the ship, personnel and equipment.

.2 Minimize equipment installed in hazardous areas to that required for operational purposes. Equipment installed in hazardous areas should be suitable and appropriately certified.

.3 Arrange hazardous areas to ensure pockets of gas cannot accumulate under normal and foreseeable failure conditions.

.4 Arrange propulsion and electrical power generating installation to be capable of sustained or restored operation in the event that a gas-fuelled essential service becomes inoperative.

.5 Provide ventilation to protect personnel from an oxygen deficient atmosphere in the event of a gas leakage.

.6 Minimize the number of ignition sources in hazardous spaces by design, arrangements and selection of suitable equipment.

.7 Arrange safe and suitable gas fuel storage and bunkering arrangements capable of taking on board and containing the gas fuel in the required state without leakage and overpressure.

.8 Provide gas piping systems, containment and overpressure relief arrangements that are of suitable design, construction and installation for their intended application.

.9 Design, construct, install, operate and protect gas-fuelled machinery, gas system and components to achieve safe and reliable operation consistent with that of oil-fuelled machinery.

.10 Arrange and locate gas storage tank rooms and machinery spaces such that a fire or explosion in either will not render the machinery/equipment in other compartments inoperable.

.11 Provide safe and reliable gas-fuel control engineering arrangements consistent with those of oil-fuelled machinery.

.12 Provide appropriate selection of certified equipment and materials that are suitable for use within gas systems.

.13 Provide gas detection systems suitable for the space concerned together with monitoring, alarm and shutdown arrangements.

.14 Provide protection against the potential effects of a gas-fuel explosion.

.15 Prevent explosion and hazardous consequences.

.16 Provide fire detection, protection and extinction measures appropriate to the hazards concerned.

.17 Provide a level of confidence in a gas-fuelled unit that is equivalent to that for an oil-fuelled unit.

.18 Ensure that commissioning, trials and maintenance of gas utilization machinery satisfy the goal in terms of reliability, availability and safety.

.19 Provide provision for procedures detailing the guidelines for safe routine and unscheduled inspection and maintenance.

.20 Provide operational safety through appropriate training and certification of crew.

.21 Provide for submission of technical documentation in order to permit an assessment of the compliance of the system and its components with the applicable rules and guidelines.

4 The Interim Guidelines address the safety of ships utilizing natural gas as fuel.

5 Natural gas (dry) is defined as gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

6 The gas composition can vary depending on the source of natural gas and the processing of the gas. Typical composition in volume (%):

Methane (C_1)	94.0%
Ethane (C_2)	4.7%
Propane (C_3)	0.8%
Butane (C_4+)	0.2%
Nitrogen	0.3%
Density gas	0.73 kg/sm^3
Density liquid	0.45 kg/dm^3
Calorific value (low)	49.5 MJ/kg
Methane number	83

The gas may be stored and distributed as compressed natural gas (CNG) or liquefied natural gas (LNG).

CHAPTER 1

GENERAL

1.1 Application

1.1.1 These Interim Guidelines apply to internal combustion engine installations in ships using natural gas as fuel. The engines may use either a single fuel (gas) or dual fuel (gas and oil fuel), and the gas may be stored in gaseous or liquid state.

1.1.2 These Interim Guidelines should be applied in addition to the relevant provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974 and the Protocol of 1988 relating thereto, as amended.

1.1.3 The Interim Guidelines are applicable to new ships. Application to existing ships should be decided by the Administration to the extent it deems necessary.

1.2 Hazards

These Guidelines address the hazards related to the arrangements for the storage, distribution and use of natural gas as a fuel.

1.3 Definitions

For the purpose of these Guidelines, unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

1.3.1 *Accidents* mean uncontrolled events that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

1.3.2 *Certified safe type* means electrical equipment that is certified safe by a recognized body based on a recognized standard[1]. The certification of electrical equipment is to correspond to the category and group for methane gas.

1.3.3 *CNG* means compressed natural gas.

1.3.4 *Control stations* mean those spaces defined in SOLAS chapter II-2 and additionally for these Guidelines, the engine control room.

1.3.5 *Double block and bleed valve* means a set of three automatic valves located at the fuel supply to each of the gas engines.

1.3.6 *Dual fuel engines* mean engines that can burn natural gas and fuel oil oil fuel simultaneously or operate on oil fuel or gas only.

1.3.7 *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].

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[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships -

Tankers – Special Features.

[2] See also definition in IEC 60092-502:1999.

1.3.8 *ESD* means emergency shutdown.

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

1.3.10 *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.

1.3.11 *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.3.12 *Hazardous area* means an area in which an explosive gas atmosphere or a flammable gas (flashpoint below 60°C) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Hazardous areas are divided into zones 0, 1 and 2 as defined below[3]:

.1 *Zone 0* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is present continuously or is present for long periods.

.2 *Zone 1* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is likely to occur in normal operation.

.3 *Zone 2* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.3.13 *Non-hazardous area* means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

1.3.14 *High-pressure piping* means gas fuel piping with maximum working pressure greater than 10 bar.

1.3.15 *IEC* means the International Electrotechnical Commission.

1.3.16 *IGC Code* means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

1.3.17 *LEL* means the lower explosive limit.

1.3.18 *LNG* means liquefied natural gas (refer to 1.3.22).

1.3.19 *Main tank valve* means a remote operated valve on the gas outlet from a gas storage tank, located as close to the tank outlet point as possible.

1.3.20 *MARVS* means the maximum allowable relief valve setting of a gas tank.

1.3.21 *Master gas fuel valve* means an automatic valve in the gas supply line to each engine located outside the machinery space for gas-fuelled engines and as close to the gas heater (if fitted) as possible.

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3 Refer also to the area classification specified in Sec. 2.5 of IEC 60079-10-1:2008 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres.

1.3.22 *Natural gas* means a gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

1.3.23 *Open deck* means a deck that is open on both ends, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.

1.3.24 *Organization* means the International Maritime Organization (IMO).

1.3.25 *Risk* means the expression of the danger that an undesired event represents to persons, to the environment or to material property. The risk is expressed by the probability and consequences of an accident.

1.3.26 *Recognized standards* means applicable international or national standards acceptable to the Administration or standards laid down and maintained by an organization which complies with the standards adopted by the Organization and which is recognized by the Administration.

1.3.27 *Safety management system* means the international safety management system as described in the ISM Code.

1.3.28 *Second barrier* means a technical measure which prevents the occurrence of a hazard if the first barrier fails, e.g., second housing of a tank protecting the surroundings from the effect of tank leaks.

1.3.29 *Semi-enclosed space* means a space limited by decks and or bulkheads in such manner that the natural conditions of ventilation are notably different from those obtained on open deck[4].

1.3.30 *Single gas fuel engine* means a power generating engine capable of operating on gas-only, and not able to switch over to oil fuel operation.

1.3.31 *SOLAS Convention* means the International Convention for the Safety of Life at Sea, 1974, as amended.

1.3.32 *Source of release* means any valve, detachable pipe joint, pipe packing, compressor or pump seal in the gas fuel system.

1.3.33 *Tank room* means the gastight space surrounding the bunker tank, containing all tank connections and all tank valves.

1.4 Survey requirements

1.4.1 Surveys should be performed and certificates issued in accordance with the provisions of SOLAS 1974, as modified by its 1988 Protocol and as amended, chapter 1, part B, regulation 6 or 7, as applicable[5].

4 Refer also to IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

5 Refer to the Revised survey guidelines under the harmonized system of survey and certification (resolution A.997(25)).

CHAPTER 2

SHIP ARRANGEMENTS AND SYSTEM DESIGN

2.1 General

2.1.1 For any new or altered concept or configuration a risk analysis should be conducted in order to ensure that any risks arising from the use of gas-fuelled engines affecting the structural strength and the integrity of the ship are addressed. Consideration should be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure.

2.1.2 The risks should be analysed using acceptable and recognized risk analysis techniques and loss of function, component damage, fire, explosion and electric shock should as a minimum be considered. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be included in the operating manual.

2.1.3 An explosion in any space containing open gas sources should not:

.1 cause damage to any space other than that in which the incident occurs;

.2 disrupt the proper functioning of other zones;

.3 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

.4 damage work areas or accommodation in such a way that people who stay in such areas under normal operating conditions are injured;

.5 disrupt the proper functioning of control stations and switchboard rooms for necessary power distribution;

.6 damage life-saving equipment or associated launching arrangements;

.7 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space; or

.8 affect other areas in the vessel in such a way that chain reactions involving, *inter alia*, cargo, gas and bunker oil may arise.

2.2 Material requirements

2.2.1 Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with gas should be in accordance with IGC Code, chapter 6, Materials of construction. For CNG tanks, the use of materials not covered by the IGC Code may be specially considered by the Administration.

2.2.2 Materials for piping system for liquefied gases should comply with the requirements of the IGC Code, section 6.2. Some relaxation may, however, be permitted in the quality of the material of open-ended vent piping, provided the temperature of the gas at atmospheric pressure is -55°C or higher, and provided no liquid discharge to the vent piping can occur. Materials should in general be in accordance with recognized standards.

2.2.3 Materials having a melting point below 925°C should not be used for piping outside the gas tanks except for short lengths of pipes attached to the gas tanks, in which case the low melting point materials should be wrapped in class A-60 insulation.

2.3 Location and separation of spaces

2.3.1 *The arrangement and location of spaces*

The arrangement and location of spaces for gas fuel storage, distribution and use should be such that the number and extent of hazardous areas is kept to a minimum.

2.3.2 *Gas compressor room*

2.3.2.1 Compressor rooms, if arranged, should be located above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these Guidelines for tank rooms.

2.3.2.2 If compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration should be of gastight type.

2.3.3 *Machinery spaces containing gas-fuelled engines*

2.3.3.1 When more than one machinery space is required for gas-fuelled engines and these spaces are separated by a single bulkhead, the arrangements should be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space.

2.3.3.2 ESD-protected machinery spaces for gas-fuelled engines should have as simple a geometrical shape as possible.

2.3.4 *Tank rooms*

2.3.4.1 Tank room boundaries including access doors should be gastight.

2.3.4.2 The tank room should not be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam the separation should be at least 900 mm and insulation to class A-60 should be fitted on the engine-room side.

2.4 Arrangement of entrances and other openings

2.4.1 Direct access through doors, gastight or otherwise, should generally not be permitted from a gas-safe space to a gas-dangerous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.2 If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.3 The tank room entrance should be arranged with a sill height of at least 300 mm.

2.4.4 Access to the tank room should as far as practicable be independent and direct from open deck. If the tank room is only partially covering the tank, this requirement should also apply to the room surrounding the tank and where the opening to the tank room is located. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided. The access trunk should be fitted with separate ventilation. It should not be possible to have unauthorized access to the tank room during normal operation of the gas system.

2.4.5 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances should be arranged with self-closing doors. An audible and visual alarm should be provided at a permanent manned location. Alarm should be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

2.5 General pipe design

2.5.1 The requirements of this section apply to gas piping. The Administration may accept relaxation from these requirements for gas piping inside gas tanks and open-ended piping after special consideration, such as risk assessment.

2.5.2 Gas piping should be protected against mechanical damage and the piping should be capable of assimilating thermal expansion without developing substantial tension.

2.5.3 The piping system should be joined by welding with a minimum of flange connections. Gaskets should be protected against blow-out.

2.5.4 The wall thickness of pipes should not be less than:

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

where:

t_0 theoretical thickness

t_0 $pD/(20Ke + p)$

where:

p design pressure (bar), refer to 2.5.5.

D outside diameter (mm).

K allowable stress (N/mm^2), refer to 2.5.6.

e = efficiency factor equal to 1 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which 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 value depending on the manufacturing process may be determined by the Administration.

b = allowance for bending (mm). The value of b should 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 give, b should be:

$$b = \frac{Dt_0}{2.5r} \text{ (mm)}$$

with:

r = mean radius of the bend (mm).

c = corrosion allowance (mm). If corrosion allowance or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%).

The minimum wall thickness should be in accordance with recognized standards.

2.5.5 The greater of the following design conditions should be used for piping, piping system and components as appropriate:

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Administration (refer to IGC Code, paragraph 4.2.6.2), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.2 the MARVS of the gas tanks and gas processing systems; or

.3 the pressure setting of the associated pump or compressor discharge relief valve if of sufficient capacity; or

.4 the maximum total discharge or loading head of the gas piping system; or

.5 the relief valve setting on a pipeline system if of sufficient capacity; or

.6 a pressure of 10 bar except for open-ended lines where it is not to be less than

5 bar.

2.5.6 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 2.5.4 should be the lower of the following values:

$$\frac{R_m}{A} \text{ or } \frac{R_e}{B}$$

where:

R_m = specified minimum tensile strength at room temperature (N/mm2).

R_e = specified lower minimum yield stress or 0.2% proof stress at room temperature (N/mm2).

A = 2.7.

B = 1.8.

For pipes made of materials other than steel, the allowable stress should be considered by the Administration.

2.5.7 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipe due to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by 2.5.4 or, if this is impractical or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

2.5.8 Gas piping systems should have sufficient constructive strength. For high pressure gas piping systems this should 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.

2.5.9 Flanges, valves, fittings, etc., should be in accordance with recognized standards taking into account the design pressure defined in 2.5.5. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 2.5.5 may be accepted.

2.5.10 All valves and expansion joints used in high pressure gas systems should be of an approved type.

2.5.11 The following types of connections may be considered for direct connection of pipe lengths (without flanges):

.1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperature below -10°C, butt welds should 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 10 bar and design temperatures -10°C or lower, backing rings should be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Administration, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.

.3 Screwed couplings should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

2.5.12 Flanges should be of the welding neck, slip-on or socket welding type. For all piping (except open-ended lines), the following apply:

.1 For design temperatures < -55°C only welding neck flanges should be used.

.2 For design temperatures < -10°C slip-on flanges should not be used in nominal sizes above 100 mm and socket welding flanges should not be used in nominal sizes above 50 mm.

2.5.13 Piping connections other than those mentioned above may be accepted upon consideration in each case.

2.5.14 Postweld heat treatment should be required for all butt welds of pipes made with carbon, carbon-manganese and low-alloy steels. The Administration may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

2.5.15 When the design temperature is -110°C or lower, a complete stress analysis for each branch of the piping system should be submitted. This analysis should take into account all stresses due to weight of pipes with cargo (including acceleration if significant), internal pressure, thermal contraction and loads induced by movements of the ship. For temperatures above -110°C, a stress analysis may be required by the Administration. In any case, consideration should be given to thermal stresses, even if calculations need not be submitted. The analysis should be carried out according to a recognized code of practice.

2.5.16 Gas pipes should not be located less than 760 mm from the ship's side.

2.5.17 Gas piping should not be led through other machinery spaces. Alternatively, double gas piping may be approved, provided the danger of mechanical damage is negligible, the gas piping has no discharge sources and the room is equipped with a gas alarm.

2.5.18 An arrangement for purging gas bunkering lines and supply lines (only up to the double block and bleed valves if these are located close to the engine) with nitrogen should be provided.

2.5.19 The gas piping system should be installed with sufficient flexibility. Arrangement for provision of the necessary flexibility should be demonstrated to maintain the integrity of the piping system in all foreseen service situations.

2.5.20 Gas pipes should be colour marked based on a recognized standard[6].

[6] Refer to EN ISO 14726:2008 Ships and marine technology - Identification colours for the content of piping systems.

2.5.21 If the fuel gas contains heavier components that may condense in the system, knock out drums or equivalent means for safely removing the liquid should be fitted.

2.5.22 All pipelines and components which may be isolated containing liquid gas should be provided with relief valves.

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

2.6 System configuration

2.6.1 *Alternative system configurations*

2.6.1.1 Two alternative system configurations may be accepted:

.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.

.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 is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type.

2.6.2 *Gas safe machinery spaces*

2.6.2.1 All gas supply piping within machinery space boundaries should be enclosed in a gastight enclosure, i.e. double wall piping or ducting.

2.6.2.2 In case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available. Alternatively, in the case of multi-engine installations, independent and separate gas supply systems for each engine or group of engines may be accepted.

2.6.2.3 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.6.3 *ESD-protected machinery spaces*

2.6.3.1 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 should be located in two or more machinery spaces not having any common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the rooms. Distribution of engines between the different machinery spaces should be such that in the case of shutdown of fuel supply to any one machinery space it is possible to maintain at least 40% of the propulsion power plus normal electrical power supply for sea-going services. Incinerators, inert gas generators or other oil fired boilers should not be located within an ESD-protected machinery space.

.2 The gas machinery, tank and valve installation spaces should contain only a minimum of such necessary equipment, components and systems as are required to ensure that any piece of equipment in each individual space maintains its principal function.

.3 Pressure in gas supply lines within machinery spaces should be less than 10 bar, e.g., this concept can only be used for low pressure systems.

.4 A gas detection system arranged to automatically shutdown the gas supply (also oil fuel supply if dual fuel) and disconnect all non-explosion protected equipment or installations should be fitted, as outlined in 5.5 and 5.6.

2.6.3.2 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.7 Gas supply system in gas machinery spaces

2.7.1 *Gas supply system for gas safe machinery spaces*

2.7.1.1 Gas supply lines passing through enclosed spaces should be completely enclosed by a double pipe or duct. This double pipe or duct should fulfil one of the following:

.1 the gas piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system should 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 should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors should comply with the required explosion protection in the installation area. The ventilation outlet should be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

2.7.1.2 The connecting of gas piping and ducting to the gas injection valves should be so as to provide complete coverage by the ducting. The arrangement should facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting should be required also for gas pipes on the engine itself, and all the way until gas is injected into the chamber.[7]

[7] If gas is supplied into the air inlet on a low pressure engine, double ducting may be omitted on the air inlet pipe on the condition that a gas detector is fitted above the engine.

2.7.1.3 For high-pressure piping the design pressure of the ducting should be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure and is given by the following expression:

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

where:

p_0 = maximum working pressure of the inner pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

k = 1.31 for CH_4

The tangential membrane stress of a straight pipe should not 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 should reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports should then be submitted.

2.7.1.4 For low pressure piping the duct should be dimensioned for a design pressure not less than the maximum working pressure of the gas pipes. The duct should also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.7.1.5 The arrangement and installation of the high-pressure gas piping should provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the main engine, without running the risk of fatigue problems. The length and configuration of the branch lines are important factors in this regard.

2.7.2 *Gas supply system for ESD-protected machinery spaces*

2.7.2.1 The pressure in the gas supply system should not exceed 10 bar.

2.7.2.2 The gas supply lines should have a design pressure not less than 10 bar.

2.8 Gas fuel storage

2.8.1 *Liquefied gas storage tanks*

2.8.1.1 The storage tank used for liquefied gas should be an independent tank designed in accordance with the IGC Code, chapter 4.

2.8.1.2 Pipe connections to the tank should normally be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted after special consideration by the Administration.

2.8.1.3 Pressure relief valves as required in the IGC Code chapter 8 should be fitted.

2.8.1.4 The outlet from the pressure relief valves should normally be located at least B/3 or 6 m, whichever is greater, above the weather deck and 6 m above the working area and gangways, where B is the greatest moulded breadth of the ship in metres. The outlets should 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 gas safe spaces; and

.2 exhaust outlet from machinery or from furnace installation.

2.8.1.5 Storage tanks for liquid gas should not be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in the IGC Code, paragraph 15.1.4. A filling limit curve for actual filling temperatures should be prepared from the formula given in the IGC Code, paragraph 15.1.2. However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

2.8.1.6 Means that are not dependent on the gas machinery system should be provided whereby liquid gas in the storage tanks can be emptied.

2.8.1.7 It should be possible to empty, purge gas and vent bunker tanks with gas piping systems. Procedures should be prepared for this. Inerting should be performed with, for instance, nitrogen, CO_2 or argon prior to venting to avoid an explosion hazardous atmosphere in tanks and gas pipes.

2.8.2 *Compressed gas storage tanks*

2.8.2.1 The storage tanks to be used for compressed gas should be certified and approved by the Administration.

2.8.2.2 Tanks for compressed gas should be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 2.8.1.4.

2.8.3 *Storage on open deck*

2.8.3.1 Both gases of the compressed and the liquefied type may be accepted stored on open deck.

2.8.3.2 The storage tanks or tank batteries should be located at least B/5 from the ship's side. For ships other than passenger ships a tank location closer than B/5 but not less than 760 mm from the ship's side may be accepted.

2.8.3.3 The gas storage tanks or tank batteries and equipment should be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

2.8.3.4 Tanks for liquid gas with a connection below the highest liquid level (see 2.8.1.2) should be fitted with drip trays below the tank which should be of sufficient capacity to contain the volume which could escape in the event of a pipe connection failure. The material of the drip tray should be stainless steel, and there should be efficient separation or isolation so that the hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid gas.

2.8.4 *Storage in enclosed spaces*

2.8.4.1 Gas in a liquid state may be stored in enclosed spaces, with a maximum acceptable working pressure of 10 bar. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 10 bar in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Administration provided the following is fulfilled in addition to 2.8.4.3:

.1 adequate means are provided to depressurize the tank in case of a fire which can affect the tank; and

.2 all surfaces within the tank room are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the tank room.

2.8.4.2 The gas storage tank(s) should be placed as close as possible to the centreline:

.1 minimum, the lesser of B/5 and 11.5 m from the ship side;

.2 minimum, the lesser of B/15 and 2 m from the bottom plating;

.3 not less than 760 mm from the shell plating.

For ships other than passenger ships and multi-hulls, a tank location closer than B/5 from the ship side may be accepted.

2.8.4.3 The storage tank and associated valves and piping should be located in a space designed to act as a second barrier, in case of liquid or compressed gas leakage. The material of the bulkheads of this space should have the same design temperature as the gas tank, and the space should be designed to withstand the maximum pressure build-up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space should be capable of containing leakage, and is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid or compressed gas. This second barrier space is in other parts of these Guidelines called "tank room". When the tank is double walled and the outer tank shell is made of cold resistant material, a tank room could be arranged as a box fully welded to the outer shell of the tank, covering all tank connections and valves, but not necessarily all of the outer tank shell.

2.8.4.4 The tank room may be accepted as the outer shell of a stainless steel vacuum insulated tank in combination with a stainless steel box welded to the outer shell, containing all tank pipe connections, valves, piping, etc. In this case the requirements for ventilation and gas detection should be made applicable to the box, but not to the double barrier of the tank.

2.8.4.5 Bilge suctions from the tank room, if provided, should not be connected to the bilge system for the rest of the ship.

2.9 Fuel bunkering system and distribution system outside machinery spaces

2.9.1 *Fuel bunkering station*

2.9.1.1 The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration. The bunkering station should be physically separated or structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.

2.9.1.2 Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding should be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

2.9.1.3 Control of the bunkering should be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level should be monitored. Overfill alarm and automatic shutdown should also be indicated at this location.

2.9.2 *Bunkering system*

2.9.2.1 The bunkering system should be so arranged that no gas is discharged to air during filling of storage tanks.

2.9.2.2 A manually-operated stop valve and a remote operated shutdown valve in series, or a combined manually-operated and remote valve should be fitted in every bunkering line close to the shore connecting point. It should be possible to release the remote-operated valve in the control location for bunkering operations and or another safe location.

2.9.2.3 If the ventilation in the ducting around the gas bunkering lines stops, an audible and visual alarm should be provided at bunkering control location.

2.9.2.4 If gas is detected in the ducting around the bunkering lines an audible and visual alarm should be provided at the bunkering control location.

2.9.2.5 Means should be provided for draining the liquid from the bunkering pipes at bunkering completion.

2.9.2.6 Bunkering lines should be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes should be gas free.

2.9.3 *Distribution outside of machinery spaces*

2.9.3.1 Gas fuel piping should not be led through accommodation spaces, service spaces or control stations.

2.9.3.2 Where gas pipes pass through enclosed spaces in the ship, they should be enclosed in a duct. This duct should be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in 5.5 should be provided.

2.9.3.3 The duct should be dimensioned according to 2.7.1.3 and 2.7.1.4.

2.9.3.4 The ventilation inlet for the duct should always be located in open air, away from ignition sources.

2.9.3.5 Gas pipes located in open air should be so located that they are not likely to be damaged by accidental mechanical impact.

2.9.3.6 High-pressure gas lines outside the machinery spaces containing gas-fuelled engines should be installed and protected so as to minimize the risk of injury to personnel in case of rupture.

2.10 Ventilation system

2.10.1 *General*

2.10.1.1 Any ducting used for the ventilation of hazardous spaces should be separate from that used for the ventilation of non-hazardous spaces. The ventilation should function at all temperature conditions the ship will be operating in. Electric fan motors should not be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

2.10.1.2 Design of ventilation fans serving spaces containing gas sources should fulfil the following:

.1 Electric motors driving fans should comply with the required explosion protection in the installation area. Ventilation fans should not 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, should 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 housing 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 In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

.4 The installation on board of the ventilation units should be such as to ensure the safe bonding to the hull of the units themselves.

2.10.1.3 Any loss of the required ventilating capacity should give an audible and visual alarm at a permanently manned location.

2.10.1.4 Required ventilation systems to avoid any gas accumulation should consist of independent fans, each of sufficient capacity, unless otherwise specified in these Guidelines.

2.10.1.5 Air inlets for hazardous enclosed spaces should be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct should have over-pressure relative to this space, unless mechanical integrity and gastightness of the duct will ensure that gases will not leak into it.

2.10.1.6 Air outlets from non-hazardous spaces should be located outside hazardous areas.

2.10.1.7 Air outlets from hazardous enclosed spaces should be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

2.10.1.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

2.10.1.9 Non-hazardous spaces with opening to a hazardous area should be arranged with an air-lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation should be arranged according to the following requirements:

.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 should 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 should be monitored.

.3 In the event of failure of the overpressure ventilation:

.1 an audible and visual alarm should 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[8].

[8] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

2.10.2 *Tank room*

2.10.2.1 The tank room for gas storage should be provided with an effective mechanical forced ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations should be demonstrated by a safety analysis.

2.10.2.2 Approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for tank room.

2.10.3 *Machinery spaces containing gas-fuelled engines*

2.10.3.1 The ventilation system for machinery spaces containing gas-fuelled engines should be independent of all other ventilation systems.

2.10.3.2 ESD-protected machinery spaces should have ventilation with a capacity of at least 30 air changes per hour. The ventilation system should ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces is 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.

2.10.3.3 The number and power of the ventilation fans should 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 out of action.

2.10.4 *Pump and compressor rooms*

2.10.4.1 Pump and compressor rooms should be fitted with effective mechanical ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

2.10.4.2 The number and power of the ventilation fans should 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 out of action.

2.10.4.3 Ventilation systems for pump and compressor rooms should be in operation when pumps or compressors are working.

2.10.4.4 When the space is dependent on ventilation for its area classification, the following should apply:

.1 During initial start-up, and after loss of ventilation, the space should be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation. Warning notices to this effect should be placed in an easily visible position near the control stand.

.2 Operation of the ventilation should be monitored.

.3 In the event of failure of ventilation, the following should apply:

.1 an audible and visual alarm should be given at a manned location;

.2 immediate action should be taken to restore ventilation; and

.3 electrical installations should be disconnected[9] if ventilation cannot be restored for an extended period. The disconnection should be made outside the hazardous areas, and be protected against unauthorized reconnection, e.g., by lockable switches.

CHAPTER 3

FIRE

SAFETY

3.1 General

3.1.1 The requirements in this chapter are additional to those given in SOLAS chapter II-2.

3.1.2 A compressor room should be regarded as a machinery space of category A for fire protections purposes.

3.2 Fire protection

3.2.1 Tanks or tank batteries located above deck should be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

3.2.2 The tank room boundaries and ventilation trunks to such spaces below the bulkhead deck should be constructed to class A-60. However, where the room is adjacent to tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces, the insulation standard may be reduced to class A-0.

3.2.3 The fire and mechanical protection of gas pipes lead through ro-ro spaces on open deck should be subject to special consideration by the Administration depending on the use and expected pressure in the pipes. Gas pipes lead through ro-ro spaces on open deck should be provided with guards or bollards to prevent vehicle collision damage.

3.2.4 The bunkering station should be separated by class A-60 divisions towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

3.2.5 When more than one machinery space is required and these spaces are separated by a single bulkhead, the bulkhead should be class A-60.

3.2.6 A compressor room in a ship not subject to the IGC Code should be regarded as a machinery space of category A for fire insulation requirements.

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[9] Intrinsically safe equipment suitable for zone 0 is not required to be switched off. Certified flameproof lighting may have a separate switch-off circuit.

3.3 Fire extinction

3.3.1 *Fire main*

3.3.1.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure is sufficient to operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

3.3.1.2 When the storage tank is located on open deck, isolating valves should be fitted in the fire main in order to isolate damage sections of the main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section of water.

3.3.2 *Water spray systems*

3.3.2.1 A water spray system should be fitted for cooling and fire prevention and to cover exposed parts of gas storage tank located above deck.

3.3.2.2 The system should be designed to cover all areas as specified above with an application rate of 10 l/min/m^2 for horizontal projected surfaces and 4 l/min/m^2 for vertical surfaces.

3.3.2.3 For the purpose of isolating damage sections, stop valves should be fitted at least every 40 m or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

3.3.2.4 The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

3.3.2.5 A connection to the ship's fire main through a stop valve should be provided.

3.3.2.6 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

3.3.2.7 The nozzles should be of an approved full bore type and they should be arranged to ensure an effective distribution of water throughout the space being protected.

3.3.2.8 An equivalent system to the water spray system may be fitted provided it has been tested for its on-deck cooling capability to the satisfaction of the Administration.

3.3.3 *Dry chemical powder fire-extinguishing system*

3.3.3.1 In the bunkering station area a permanently installed dry chemical powder extinguishing system should cover all possible leak points. The capacity should be at least 3.5 kg/s for a minimum of 45 s discharges. The system should be arranged for easy manual release from a safe location outside the protected area.

3.3.3.2 One portable dry powder extinguisher of at least 5 kg capacity should be located near the bunkering station.

3.4 Fire detection and alarm system

3.4.1 *Detection*

3.4.1.1 An approved fixed fire detection system should be provided for the tank room and the ventilation trunk for tank room below deck.

3.4.1.2 Smoke detectors alone should not be considered sufficient for rapid fire detection.

3.4.1.3 Where the fire detection system does not include means of remotely identifying each detector individually, the detectors should be arranged on separate loops.

3.4.2 *Alarms and safety actions*

3.4.2.1 Required safety actions at fire detection in the machinery space containing gas-fuelled engines and tank room are given in table 1 of chapter V. In addition, the ventilation should stop automatically and fire dampers are to close.

CHAPTER 4

ELECTRICAL

SYSTEMS

4.1 General

4.1.1 The provisions of this chapter should be applied in conjunction with applicable electrical requirements of part D of SOLAS chapter II-1.

4.1.2 Hazardous areas on open deck and other spaces not defined in this chapter should be decided based on a recognized standard[10]. The electrical equipment fitted within hazardous areas should be according to the same standard.

4.1.3 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard[11].

4.1.4 Electrical equipment fitted in an ESD-protected machinery space should fulfil the following:

.1 In addition to fire and hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans should be certified safe for hazardous area zone 1.

.2 All electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 should be automatically disconnected, if gas concentrations above 20% LEL is detected on two detectors in the space containing gas-fuelled engines.

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

[11] The type of equipment and installation requirements should comply with IEC standard 60092-502: IEC 60092-502:1999 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.

4.1.5 There should be an equalization connection between the bunker supplier and the bunkering station on the ship when a flammable gas/liquid is transferred.

4.1.6 Cable penetrations should satisfy the requirements regulating the dispersion of gas.

4.2 Area classification

4.2.1 *General*

4.2.1.1 Area 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 be operated safely in these areas.

4.2.1.2 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[12]. See also 4.3 below.

4.2.1.3 Area classification of a space may be dependent on ventilation[13].

4.2.1.4 A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure. Requirements to such pressurization are given in 2.10.

4.2.1.5 Ventilation ducts should have the same area classification as the ventilated space.

4.3 Definition of hazardous area zones

4.3.1 *Hazardous area zone 0*

This zone includes:

.1 the interiors of gas tanks, any pipework of pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.[14]

4.3.2 *Hazardous area zone 1*

This zone includes:

.1 tank room;

.2 gas compressor room arranged with ventilation according to 2.10.4;

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12 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 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

13 Refer to standard IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features for tankers, table 1.

14 Instrumentation and electrical apparatus in contact with the gas or liquid gas should be of a type suitable for

zone 0. Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber should be of intrinsically safe type Ex-ia.

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet[15], bunker manifold valve, other gas valve, gas pipe flange, gas pump-room ventilation outlets and gas 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 gas compressor and pump room entrances, gas pump and compressor room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g., ducts around gas pipes, semi-enclosed bunkering stations; and

.7 the ESD-protected machinery space is considered as non-hazardous area during normal operation, but changes to zone 1 in the event of gas leakage.

4.3.3 *Hazardous area zone 2*

This zone includes:

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1[16].

CHAPTER 5

CONTROL, MONITORING AND SAFETY SYSTEMS

5.1 General

5.1.1 A local reading pressure gauge should be fitted between the stop valve and the connection to shore at each bunker pipe.

5.1.2 Pressure gauges should be fitted to gas pump discharge lines and to the bunkering lines.

5.1.3 A bilge well in each tank room surrounding an independent liquid gas storage tank should be provided with both a level indicator and a temperature sensor. Alarm should be given at high level in bilge well. Low temperature indication should lead to automatic closing of main tank valve.

5.2 Gas tank monitoring

5.2.1 Gas tanks should be monitored and protected against overfilling as required in the IGC Code, sections 13.2 and 13.3.

[15] Such areas are, for example, all areas within 3 m of gas tank hatches, ullage openings or sounding pipes for gas tanks located on open deck and gas vapour outlets.

[16] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features or

IEC 60079-10-1:2008 Explosive atmospheres - Part 10-1: Classification of areas, according to the area classification., as applicable if not otherwise specified in this standard.

5.2.2 Each tank should be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, low pressure alarm should be provided on the bridge. The alarms should be activated before the set pressures of the safety valves are reached.

5.3 Gas compressor monitoring

Gas compressors should be fitted with audible and visual alarms both on the bridge and in the engine-room. As a minimum the alarms should be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

5.4 Gas engine monitoring

5.4.1 Additional to the instrumentation provided in accordance with SOLAS chapter II-1, Part C, indicators should 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.

5.4.2 Auxiliary systems where gas may leak directly into the system medium (lubricating oil, cooling water) should be equipped with appropriate gas extraction measures fitted directly after the outlet from the engine in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the open.

5.5 Gas detection

5.5.1 Permanently installed gas detectors should be fitted in the tank room, in all ducts around gas pipes, in machinery spaces of the ESD-protected type, compressor rooms and other enclosed spaces containing gas piping or other gas equipment without ducting. In each ESD-protected machinery space, two independent gas detector systems should be required.

5.5.2 The number of detectors in each space should be considered taking size, layout and ventilation of the space into account.

5.5.3 The detection equipment should be located where gas may accumulate and/or in the ventilation outlets. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

5.5.4 An audible and visible alarm should be activated before the vapour concentration reaches 20% of the lower explosion limit (LEL). For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The protective system should be activated at a LEL of 40%.

5.5.5 Audible and visible alarms from the gas detection equipment should be located on the bridge and in the engine control room.

5.5.6 Gas detection for gas pipe ducts and machinery spaces containing gas-fuelled engines should be continuous without delay.

5.6 Safety functions of gas supply systems

5.6.1 Each gas storage tank should be provided with a tank valve capable of being remote operated and should be located as close to the tank outlet as possible.

5.6.2 The main gas supply line to each engine or set of engines should 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 valves should be situated in the part of the piping that is outside machinery space containing gas-fuelled engines, and placed as near as possible to the installation for heating the gas, if fitted. The master gas-fuel valve should automatically cut off the gas supply as given in table 1.

5.6.2.1 The automatic master gas fuel valve should be operable from a reasonable number of places in the machinery space containing gas-fuelled engines, from a suitable location outside the space and from the bridge.

5.6.3 Each gas consuming equipment should be provided with a set of "double block and bleed" valves. These valves should be arranged as outlined in .1 or .2 (respectively shown as alternatives 1 and 2 in figure 1) so that when automatic shutdown is initiated as given in table 1, this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically and:

.1 two of these valves should be in series in the gas fuel pipe to the gas consuming equipment. The third valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

.2 the function of one of the valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

5.6.3.1 The two block valves should be of the fail-to-close type, while the ventilation valve should be fail-to-open.

5.6.3.2 The double block and bleed valves should also be used for normal stop of the engine.

5.6.4 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve should be ventilated, if reverse flow from the engine to the pipe must be assumed.

5.6.5 There should 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.

5.6.6 For one-engine installations and multi-engine installations, 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. Examples for the high-pressure system are shown in figures 1 and 2.

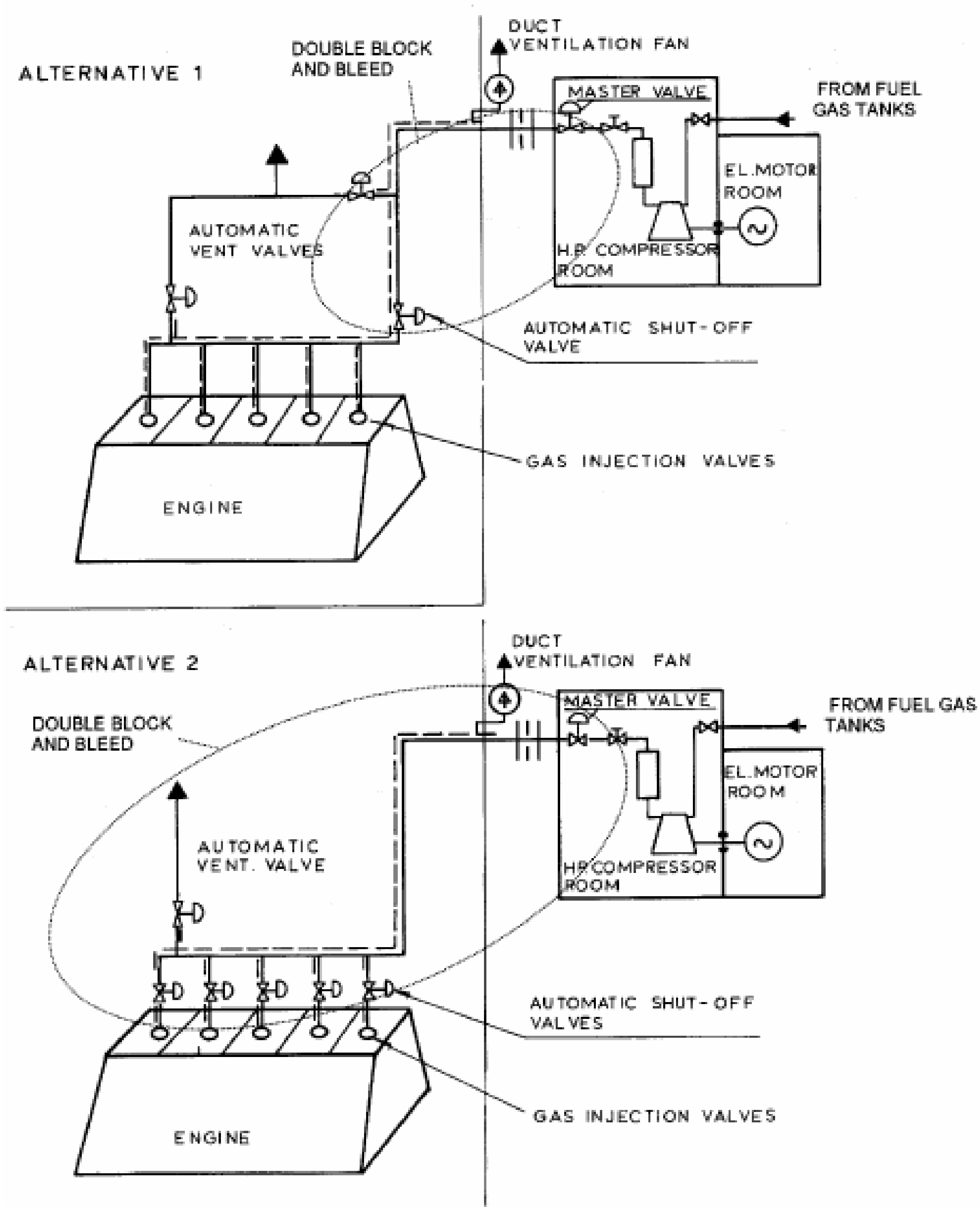

Figure 1

Alternative supply valve arrangements for high-pressure installations (single engine or separate master valve arrangement)

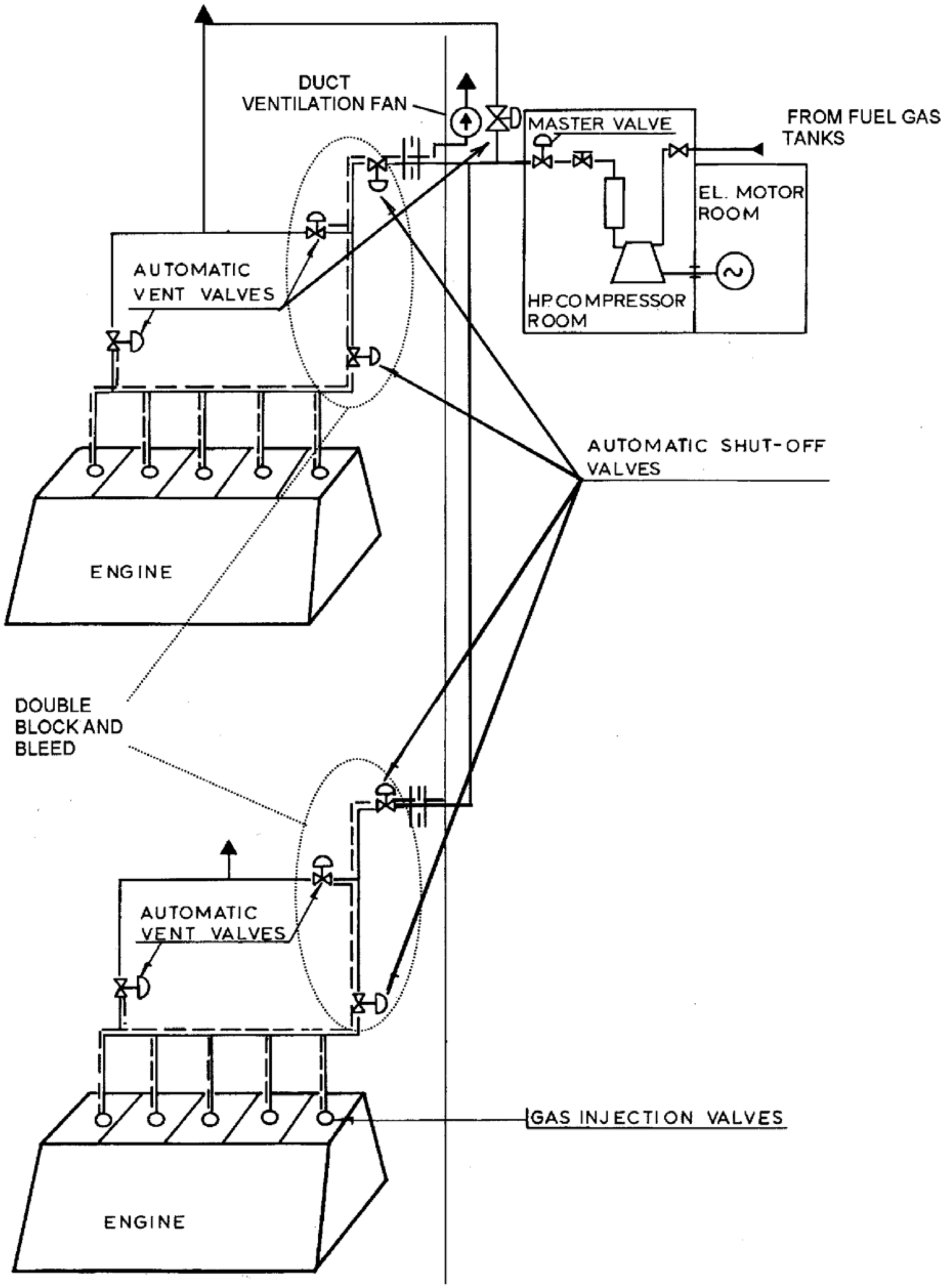

Figure 2

Alternative supply valve arrangements for high-pressure installations (multi-engine installation)

5.6.7 The total loss of ventilation in a machinery space for a single fuelled gas system should, additionally to what is given in table 1, lead to one of the following actions:

.1 *For a gas electric propulsion system with more than one machinery space*: Another engine should start. When the second engine is connected to bus-bar, the first engine should be shutdown automatically.

.2 *For a direct propulsion system with more than one machinery space*: The engine in the room with defect ventilation should be manually shutdown, if at least 40% propulsion power is still available after such a shutdown.

If only one machinery space for gas-fuelled engines is fitted and ventilation in one of the enclosed ducts around the gas pipes is lost, the master gas fuel and double block and bleed valves in that supply line should close automatically provided the other gas supply unit is ready to deliver.

5.6.8 If the gas supply is shut off due to activation of an automatic valve, the gas supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the gas supply lines.

5.6.9 If a gas leak leading to a gas supply shutdown occurs, the gas fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

5.6.10 A signboard should be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the gas pipes, should not be done when the engine(s) is running on gas.

Table 1 - Monitoring of gas supply system to engines

Parameter	**Alarm**	**Automatic shutdown of main tank valve**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comment**
Gas detection in tank room above 20% LEL	X			
Gas detection on two detectors [1] in tank room above 40% LEL	X	X		
Fire detection in tank room	X	X		
Bilge well high level tank room	X			
Bilge well low temperature in tank room	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines above 20% LEL	X			
Gas detection on two detectors [1] in duct between tank and machinery space containing gas-fuelled engines above 40% LEL	X	X [2]		
Gas detection in compressor room above 20% LEL	X			

Gas detection on two detectors[1] in compressor room above 40% LEL	X	X [2]		

Parameter	**Alarm**	**Automatic shutdown of main tank valve**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comment**
Gas detection in duct inside machinery space containing gas-fuelled engines above 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors[1)] in duct inside machinery space containing gas-fuelled engines above 40% LEL	X		X [3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in machinery space containing gas-fuelled engines above 20% LEL	X			Gas detection only required for ESD protected machinery space
Gas detection on two detectors[1)] in machinery space containing gas-fuelled engines above 40% LEL	X		X	Gas detection only required for ESD protected machinery space containing gas-fuelled engines. It should also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines [6)]	X		X [2) 4)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines [6)]	X		X [3) 4)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in machinery space containing gas-fuelled engines	X		X	ESD protected machinery space containing gas-fuelled engines only
Fire detection in machinery space containing gas-fuelled engines	X		X	
Abnormal gas pressure in gas supply pipe	X		X [4)]	
Failure of valve control actuating medium	X		X[5)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[5)]	
Emergency shutdown of engine manually released	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self monitoring type the installation of a single gas detector can be permitted.
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) This parameter is not to lead to shutdown of gas supply for single fuel gas engines, only for dual fuel engines.
5) Only double block and bleed valves to close.
6) If the duct is protected by inert gas (see 2.7.1) then loss of inert gas overpressure is to lead to the same actions as given in this table.

CHAPTER 6

COMPRESSORS AND GAS ENGINES

6.1 Gas compressors

6.1.1 The fuel gas compressor should be fitted with accessories and instrumentation necessary for efficient and reliable function.

6.1.2 The gas compressor and fuel gas supply should be arranged for manual remote emergency stop from the following locations:

.1 cargo control room (relevant for cargo ships only);
.2 navigation bridge;
.3 engine control room; and
.4 fire control station.

6.2 Gas engine design general

6.2.1 The last gas valve prior to the gas engine should be controlled by the engine control system or by the engine gas demand.

All gas engine components, gas engine systems and gas engine subsystems should be designed to:

.1 exclude any explosion at all possible situations; or

.2 to allow explosions without detrimental effect and to discharge to a safe location. The explosion event should not interrupt the safe operation of the engine unless other safety measures allow the shutdown of the affected engine.

6.2.1.1 When gas is supplied in a mixture with air through a common manifold, sufficient flame arrestors should be installed before each cylinder head. The mixture inlet system should be designed to withstand explosions of mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed in a way that it discharges to a safe location; or

.2 documentation demonstrating that the mixture inlet system has sufficient strength to contain the worst case explosion.

6.2.1.2 The exhaust system should be designed to withstand explosions of unburned mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed such that they discharge to a safe location; or

.2 documentation showing that the exhaust system has sufficient strength to contain the worst case explosion.

6.2.1.3 The crankcase of gas engines should be provided with:

.1 crankcase explosion relief valves of a suitable type with sufficient relief area. The relief valves should be installed in way of each crank throw and should be arranged or provided with means to ensure that discharge from them is so directed as to minimize the possibility of injury to personnel. Refer to SOLAS regulations II-1/27 and 47.2; or

.2 documentation showing that the crankcase has sufficient strength to contain the worst case explosion.

6.2.1.4 It should be ensured that the explosion of unburned mixture within the exhaust system or the crankcase or the explosion of mixture within the mixture inlet is allowed without detrimental effect.

6.2.2 The design of piping on gas engines should follow the requirements in chapter 2.6 "System configuration" and chapter 2.7 "Gas supply system in gas machinery spaces".

6.2.3 The combustion of the gas mixture should be monitored. This can be achieved by monitoring of the exhaust gas or combustion chamber temperature.

6.2.4 The exhaust pipes of gas-fuelled engines should not be connected to the exhaust pipes of other engines or systems.

6.3 Requirements dual fuel engines

6.3.1 Start and normal stop should be on oil fuel only. Gas injection should not be possible without a corresponding pilot oil injection. The amount of pilot fuel fed to each cylinder should be sufficient to ensure a positive ignition of the gas mixture.

6.3.2 In case of shut-off of the gas fuel supply, the engines should be capable of continuous operation by oil fuel only.

6.3.3 Changeover to and from gas fuel operation should only be possible at a power level and under conditions where it can be done with acceptable reliability as demonstrated through testing. On power reduction the changeover to oil fuel is to be automatic. The changeover process itself from and to gas operation should be automatic. Manual interruption should be possible in all cases.

6.3.4 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the oil fuel. It should not be possible to shut off the supply pilot fuel without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4 Requirements gas-only engines

6.4.1 The starting sequence should 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.

6.4.2 If ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve the gas supply valve should be automatically shut off and the starting sequence terminated. It should be ensured by any mean that any unburned gas mixture is flushed away from the exhaust system.

6.4.3 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the ignition. It should not be possible to shut off the ignition without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4.4 For constant speed engines the shut down sequence should be such that the engine gas supply valve closes at idle speed and that the ignition system is kept active until the engine is down to standstill.

CHAPTER 7

MANUFACTURE, WORKMANSHIP AND TESTING

7.1 General

The manufacture, testing, inspection and documentation should be in accordance with recognized standards and the specific requirements given in these Guidelines.

7.2 Gas tanks

Tests related to welding and tank testing should be in accordance with the IGC Code, sections 4.10 and 4.11.

7.3 Gas piping systems

7.3.1 The requirements for testing should apply to gas piping inside and outside the gas tanks. However, relaxation from these requirements may be accepted for piping inside gas tanks and open-ended piping.

7.3.2 Welding procedure tests should be required for gas piping and should be similar to those required for gas tanks in the IGC Code, paragraph 6.3.3. Unless otherwise especially agreed with the Administration, the test requirements should be in accordance with 7.3.3 below.

7.3.3 Test requirements:

.1 Tensile tests: Generally, tensile strength should not be less than the specified minimum tensile strength for the appropriate parent materials. The Administration may also require that the transverse weld tensile strength should not be less than the specified tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture should be reported for information.

.2 Bend tests: No fracture should be acceptable after a 180° bend over a former of a diameter four times the thickness of the test piece, unless otherwise specially required or agreed with the Administration.

.3 Charpy V-notch impact tests: Charpy tests should be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (*E*), should be no less than 27 J. The weld metal requirements for sub-size specimens and singe energy values should be in accordance with the IGC Code paragraph 6.1.4. The results of fusion line and heat affected zone impact tests should show a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub-size specimens, the minimum average energy (E) should be in accordance with the IGC Code, paragraph 6.1.4. If the material thickness does not permit machining either full-sized or standard sub-size specimens, the testing procedure and acceptance standards should be in accordance with recognized standards.

Impact testing is not required for piping with thickness less than 6 mm.

7.3.4 In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests should be required:

.1 For butt welded joints for piping systems with design temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, 100% radiographic testing should be required.

.2 When such butt welded joints of piping sections are made by automatic welding processes in the pipe fabrication shop, upon special approval, the extent of radiographic inspection may be progressively reduced but in no case to less than 10% of the joints. If defects are revealed the extent of examination should be increased to 100% and shall include inspection of previously accepted welds. This special approval should only be granted if well-documented quality assurance procedures and records are available to enable the Administration to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Administration depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes should be radiographed.

Butt welded joints of high-pressure gas pipes and gas supply pipes in ESD-protected machinery spaces should be subjected to 100% radiographic testing.

The radiographs should be assessed according to a recognized standard[17].

7.3.5 After assembly, all gas piping should be subjected to a hydrostatic test to at least 1.5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board should be hydrostatically tested to at least 1.5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing methods should be submitted for approval.

7.3.6 After assembly on board, each gas piping system should be subjected to a leak test using air, halides or other suitable medium.

7.3.7 All gas piping systems including valves, fittings and associated equipment for handling gas should be tested under normal operating condition before set into normal operation.

[17] Refer to ISO 5817:2003, Arc-welded joints in steel – Guidance on quality levels for imperfections, and should at least meet the requirements for quality level B.

7.4 Ducting

If the gas piping duct contains high-pressure pipes the ducting should be pressure tested to at least 10 bar.

7.5 Valves

Each size and each type of valve intended to be used at a working temperature below -55°C should be prototype tested as follows. It should be subjected to a tightness test at the minimum design temperature or lower and to a pressure not lower than the design pressure for the valves. During the test, the good operation of the valve should be ascertained.

7.6 Expansion bellows

7.6.1 The following prototype tests should be performed on each type of expansion bellows intended for use in gas piping, primarily on those used outside the gas tank:

.1 An overpressure test. A type element of the bellows, not pre-compressed, should be pressure tested to a pressure not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 min.

.2 A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc.) at twice the design pressure at the extreme displacement conditions recommended by the manufacturer. No permanent deformations should be allowed. Depending on materials the test may be required to be performed at the minimum design temperature.

.3 A cyclic test (thermal movements). The test should be performed on a complete expansion joint, which is to successfully 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 room temperature, when conservative, is permitted.

.4 A cyclic fatigue test (ship deformation). The test should be performed on a complete expansion joint, without internal pressure, by simulating the bellow 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.

7.6.2 The Administration may waive performance of the tests specified in 7.6.1, provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1 bar, this documentation should include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

CHAPTER 8

OPERATIONAL AND TRAINING REQUIREMENTS

8.1 Operational requirement

8.1.1 The whole operational crew of a gas-fuelled cargo and a passenger ship should have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board.

8.1.2 Additionally, crew members with a direct responsibility for the operation of gas-related equipment on board should receive special training. The company should document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

8.1.3 Gas-related emergency exercises should be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents should be reviewed and tested.

8.1.4 A training manual should be developed and a training programme and exercises should be specially designed for each individual vessel and its gas installations.

8.2 Gas-related training

8.2.1 *Training in general*

The training on gas-fuelled ships is divided into the following categories:

.1 category A: Basic training for the basic safety crew;
.2 category B: Supplementary training for deck officers; and
.3 category C: Supplementary training for engineer officers.

8.2.1.1 *Category A training*

.1 The goal of the category A training should provide the basic safety crew with a basic understanding of the gas in question as a fuel, the technical properties of liquid and compressed gas, explosion limits, ignition sources, risk reducing and consequence reducing measures, and the rules and procedures that must be followed during normal operation and in emergency situations.

.2 The general basic training required for the basic safety crew is based on the assumption that the crew does not have any prior knowledge of gas, gas engines and gas systems. The instructors should include one or more of the suppliers of the technical gas equipment or gas systems, alternatively other specialists with in-depth knowledge of the gas in question and the technical gas systems that are installed on board.

.3 The training should consist of both theoretical and practical exercises that involve gas and the relevant systems, as well as personal protection while handling liquid and compressed gas. Practical extinguishing of gas fires should form part of the training, and should take place at an approved safety centre.

8.2.1.2 *Categories B and C training*

.1 Deck and engineer officers should have gas training beyond the general basic training. Category B and category C training should be divided technically between deck and engineer officers. The company's training manager and the master should determine what comes under deck operations and what comes under engineering.

.2 Those ordinary crew members who are to participate in the actual bunkering work, as well as gas purging, or are to perform work on gas engines or gas installations, etc., should participate in all or parts of the training for category B/C. The company and the master are responsible for arranging such training based on an evaluation of the concerned crew member's job instructions/area of responsibility on board.

.3 The instructors used for such supplementary training should be the same as outlined for category A.

.4 All gas-related systems on board should be reviewed. The ship's maintenance manual, gas supply system manual and manual for electrical equipment in explosion hazardous spaces and zones should be used as a basis for this part of the training.

.5 This regulation should be regularly reviewed by the company and onboard senior management team as part of the SMS system. Risk analysis should be emphasized, and any risk analysis and sub-analyses performed should be available to course participants during training.

.6 If the ship's own crew will be performing technical maintenance of gas equipment, the training for this type of work should be documented.

.7 The master and the chief engineer officer should give the basic safety crew on board their final clearance prior to the entry into service of the ship. The clearance document should only apply to gas-related training, and it should be signed by both the master/chief engineer officer and the course participant. The clearance document for gas-related training may be integrated in the ship's general training programme, but it should be clearly evident what is regarded as gas-related training and what is regarded as other training.

.8 The training requirements related to the gas system should be evaluated in the same manner as other training requirements on board at least once a year. The training plan should be evaluated at regular intervals.

8.3 Maintenance

8.3.1 A special maintenance manual should be prepared for the gas supply system on board.

8.3.2 The manual should include maintenance procedures for all technical gas-related installations, and should comply with the recommendations of the suppliers of the equipment. The intervals for, and the extent of, the replacement/approval of gas valves should be established. The maintenance procedure should specify who is qualified to carry out maintenance.

8.3.3 A special maintenance manual should be prepared for electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a recognized standard.[18]

8.3.4 Any personnel that should carry out inspections and maintenance of electrical installations in explosion hazardous spaces should be qualified pursuant to IEC 60079-17, item 4.2.

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[18] Refer to IEC 60079-17:2007 Explosive atmospheres - Part 17: Electrical installations inspection and maintenance.

Appendix 3. Conducting risk analyses for the construction and operation of ships using fuel with a flash point below 60°C

§ 1. *Guidelines*

1. . The analysis carried out by identification of adverse events, assessment of the probability that they may arise and the associated consequences.

2. The analysis will ensure a comprehensive safety assessment of the entire gas powered ship concept.

3. The analysis shall be performed in accordance with recognized procedures and methods as well as updated software. Guidelines for planning, implementing and using risk analysis can be, for example, the requirements for risk Norwegian Standard NS-5814.1 The international standard IEC 60300-3-9 Risk Analysis of Technological Systems provides similar guidelines. The methods described in the standards and guidelines deal with the most widely used risk analysis methods.

4. There should be appointed a coordinator who is responsible for monitoring and communication between the parties during the process of risk analysis.

1 The guidelines for this are published in SINTEF report no STF75A91021.

§ 2. *Method*

1. The risk analysis shall describe methods and computer programs, national or international standards that are used.

2. Data sources, data and calculations used for preparation of the analysis shall be specified and documented.

§ 3. *General requirements for risk analysis*

Risk analysis shall be performed by bodies that can demonstrate knowledge and experience from the preparation of risk analysis and have knowledge of ship construction, technical and operational systems.

1. The risk analysis shall meet the requirements set out in § 6 of the Regulations here and specified in this Appendix and the requirement for risk analysis mentioned in other paragraphs.

2. The analysis shall document that any gas explosion is controlled so that people, equipment and vessels are not damaged cf. Regulations § 5.

3. The scope of the analysis can be reduced if satisfactory risk for identical structures and systems with the same type of gas previously documented to the Norwegian Maritime Directorate.

4. In addition to technical malfunctions and the like shall also human error included in the analysis.

§ 4. *Subanalyses*

1. *Conseptual Analysis*

Concept analysis shall include all the ship's gas-related arrangements and systems, their location relative to each other and any redundancy. The analysis must include a reliability and vulnerability assessment in which human error, design constraints and functional- and system failures system are included. All suppliers of equipment and systems for gas plant on board shall be subject to a reliability and vulnerability assessment.[1]

The result of the whole concept analysis should govern the selection of design solutions for ships and equipment, so that the current functional requirements are met. Risk and impact reduction measures should only include matters relating to gas operation. These measures should be identified and summarized in the analysis. The description shall indicate which structural and operational measures required to be implemented in order to get the security level at least equal to those of diesel-powered ships.

2. *Contingency Analysis*

This analysis should be conducted on the basis of accidents and design explosion events that may occur on board. The ship's security, safety and response systems, and the crew positions and duties in an alarm situation shall be implemented in the contingency analysis. The contingency analysis shall indicate any specific contingency related to gas operation. The results of the contingency analysis shall be incorporated in the ship's emergency plan.

3. *Explosion Analysis*

Explosion analysis must determine the probability that an explosive gas mixture, the likelihood of ignition of the gas and the effects of a possible explosion. The analysis should show whether the ship meets the requirements of the Regulations §§ 5 and 6. The analysis includes confirming the dimensions of the explosion panels / ducts / hatches in explosive spaces and the strength of the explosive rooms. Maximum pressure shall be calculated from design explosion event. Explosion pressure relief to open air or relief spaces shall be taken into account.

1 Guidelines concerning vulnerability assessment is given e.g. in the book System Reliability Theory; Models, Statistical Methods and Applications (ISBN 0-471-4713).