DRAFT INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)
(including round 1 summary)

INDEX

1 Preamble

[The purpose of this Code is to provide an international standard for ships, other than vessels covered by the IGC Code, operating with gas or low-flashpoint liquids as fuel.

The basic philosophy of the Code is to provide mandatory criteria for the arrangement and installation of machinery, equipment and systems for vessels operating with gas or low-flashpoint liquids as 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 the 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 the Code, taking into account both experience and technical developments.]

[The Code addresses all areas that need special consideration for the usage of the gas or low-flashpoint liquids as 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 Code is structured into three parts:

.1 Part A: Design including sub-parts A-1 to A-x for some specific fuels addressed by this Code;

.2 Part B: Manufacturing; and

.3 Part C: Operation.]

PART A

2 GENERAL

[2.1 Application

(Note: Application is not yet decided)

2.1.1 Unless expressly provided otherwise this Code applies to ships regardless of size, including those of less than 500 gross tonnage, [other than vessels covered by the IGC Code,] operating with fuels as defined in 2.2.15.

2.1.2 Subject to 2.1.1, unless expressly provided otherwise this Code shall apply to ships:

.1 for which the building contract is placed on or after [dd/mm/yyyy(date of entry into force)]; or

.2 in the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after dd/mm/yyyy]; or

.3 the delivery of which is on or after [dd/mm/yyyy].

2.1.3 A ship, irrespective of the date of construction, which is converted to [consume gas, dual fuel, multi fuel or low-flashpoint fuel as included in table 6.6.4.2] [use of gas or low-flashpoint fuel as defined in 2.2.15 for main or auxiliary machinery] on or after [dd/mm/yyy] shall comply with this Code.2.1.4. This Code shall apply in addition to the relevant provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974 and the Protocol of 1998 relating thereto, as amended.

2.1.4 This Code is applicable to all low flash point fuels. Fuel in the context of this Code is defined in 2.2.15. Other gases or low-flashpoint fuels may be considered by the Administration provided the requirements of section 3 and section 4 are met and that alternative design analysis according to paragraph 2.3 has been approved. The fuels are to be designated at construction or conversion and those for which the vessel is built may not be changed during service without the agreement of the Administration.]

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 Administration is .....]

2.2.3 [*Alternative design* means an engineering analysis, evaluation and approval of a design deviating from the prescriptive requirements.]

2.2.4 *Breadth (B)* means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell, and to the outer surface of the hull in a ship with a shell of any other material. The breadth (B) shall be measured in metres.]

2.2.4*bis 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.]

2.2.5 *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]

2.2.6 *CNG* means compressed natural gas ref.2.2.19.

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

2.2.8 *Design pressure* means…..

XX *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.

XX *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.

[7.4.1.4*bis* *Service tank pressure* is the gas pressure in the tank(s) needed for the normal service of the ship project]

2.2.9 [*Double block and bleed valve* means a set of three automatic valves located at the fuel supply to each of the gas engines.]

Alternatively:

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]

2.2.11*bis* *Energy converters* mean

2.2.12 *ESD* means emergency shutdown.

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.

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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.

2.2.14*bis* *Fatique criterion for type C Tanks*
(Note:Type C Tanks according chapter 7 are designed in a way that an initial crack will not propagate through more than 50 per cent of the tank wall thickness during the lifetime of the tank if the maximum number of pressure cycles and operation under north Atlantic conditions are assumed.)

2.2.15 *Fuel* [in the context of this code] are the following gas fuels and low-flashpoint fuels:

Natural gas	liquid and compressed
Propane	liquid and compressed
Butane (i and n)	liquid [and compressed]
Propane/Butane mixtures	liquid [and compressed
Ethyl alcohol	[liquid]
Methyl alcohol	[liquid]]
Hydrogen	[liquid and] compressed]
Dimethyl-ether	liquid]

2.2.16 *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, and will have to fulfil the requirements for both spaces;

(Note: Requirements in definition)

.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. [Welding joints between the fuel tank and the first flanges of the pipes connected to the fuel tank are not considered as tank connections in the case where these joints satisfy the requirements of this Code for the fuel tank.] The space shall be gas tight towards adjacent spaces and able to safely contain any leakage[1] from the tank in case of leakage in the tank connections or other connections or equipment, without this leakage spreading to other spaces, or leading to unsafe following incidents. The space shall be thermally insulated from ship steel as required to protect the hull from temperatures below those allowable.]

(Note: move to chapter 7)

Add footnote: The leakage from connections fastened by bolts such as flange connection is considered as droplet, and full bore discharge is not considered where the connection is maintainable. (Note: This footnote is questioned)

2.2.x [*Fuel preparation room]……*

2.2.x [*Tank connection spaces* .....(No definition in the IGC Code)]

2.2.17 *Fuel cell* means [a source of electrical power in which the chemical energy of the fuel I converted directly into electrical energy by electrochemical oxidation]

2.2.18 *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

2.2.19 *Gas only engine* means a power generating engine capable of operating on gas-only, [and not able to switch over to oil fuel operation].

2.2.20 Hazardous area mean an area in which an explosive gas atmosphere or a flammable gas or vapour 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 or any other equipment that may provide potential sources of ignition].

Hazardous areas are divided into zone 0, 1 and 2 as defined below.[3]

.1 *Zone 0* is an area in which an explosive gas atmosphere or a flammable gas or vapour 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 or vapour is likely to occur in normal operation.

.3 *Zone 2* is an area in which an explosive gas atmosphere or a flammable gas or vapour 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.

2.2.21 *High pressure piping* means gas fuel piping with maximum working pressure greater than 10 bar.

2.2.22 *IEC means* the International Electrotechnical Commission.

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

2.2.23 *LEL* means the lower explosive limit.

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

2.2.25 *LNG* means liquefied natural gas, ref.2.1.23.
(Note: Need the explanation in the preamble of the guidelines?)

2.2.26 *MARVS* means the maximum allowable relief valve setting

2.2.27 *MAWP* means the Maximum allowable working pressure of a system component or tank.

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[3] *Refer* also to the area classification specified in Sec.2.5of IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres.

XX *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. Membrane tanks are covered in 7.4.23.

2.2.28 *Multi fuel engines* means engines that can use two or more different fuels that are separate from each other, [and which do not require a pilot fuel or spark device for ignition].

2.2.29 *Non-hazardous area* means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

2.2.30 *Normal operating pressure* means…..

[2.2.31 *Open deck* means a deck that at least is open on both ends/sides, 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] [where vapours may accumulate].
(Note: It is proposed that the bottom should be open with reference to the IGC-Code)

2.2.32 *Pilot fuel* means…….

2.2.32*bis* *Recognized organization* means an organization recognized by an Administration in accordance with IMO resolutions A.739(18) and A.789(19).

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

2.2.34 *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] from BLG 17/8/2.

2.2.35 *Secondary[protection]* means that a failure of the first barrier will not lead to a hazard because of the secondary protection.

2.2.36 *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, winbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.[4]

2.2.37 *Source of release* means any [location in the fuel system?] that can potentially release a flammable fuel]

Alternatively
2.2.37 *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 may be formed under normal operating conditions, for example valves and flanges in cargo piping systems.

[2.2.38 *Unacceptable loss of power* means that it is not possible to maintain the power for [manoeuvrability] [main propulsion] and for essential [power supply] [services].
(Note: Text from SOLAS to be considered: normal operation of propulsion machinery can be sustained…" with "partial reduction in propulsion capability]

[2.2.39 *Vapour pressure* is the equilibrium pressure of the saturated vapour above the liquid, expressed in Pascal (Pa) absolute at a specified temperature.]

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

Possible additional definitions:
gas heater, open gas source, low melting point, consumer, company, fuel conditioning, , first barrier, essential machinery, boilers...

(Note: For LNG fuelled ships, while the definition of "gas" is given in paragraph 2.2.18, the word "gas" (or "fuel")has following different meanings:
.1 gas (fuel) vapour not including liquefied gas (fuel);
.2 liquefied gas (fuel); or
.3 .1 and .2 .

In our understanding, for example,
the "gas" in paragraph 15.5.1 means .1 above;
the "gas" in paragraph 15.3.2 and 15.4.1 means .2 above; and
the "gas" or "fuel" in paragraph 8.2.3, 8.2.4, 8.3.1, etc. means .3 above.

These wordings (definitions) should be cleaned up at later stage, ex. at drafting group, in order to avoid confusions and to ensure the intended safety level.)

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:

- deviate from those set out in this Code, or
- 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 chapter II-1 Part F, Regulation 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 the Code.

2.4 Survey and certification

2.4.1 Surveys shall be performed and certification 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].

(Note: If agreed to require a certificate information on portable tanks should be included and we need to develop a form of certificate for inclusion in the IGF-Code)

3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

3.1.1 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

[5] Refer to resolution A.997(25) Revised survey guidelines under the harmonized system of survey and certification

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.]

3.2.2*bis* The design philosophy shall ensure that the gas fuel installation is safe without compromising the required availability of power generation and propulsion] [ensuring fuel availability for power needed for safe maneuvering of the vessel].

3.2.3 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.

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

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

3.2.6 System components shall be protected against external damages.

3.2.7 Sources of ignition in hazardous areas shall be eliminated 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 taking on board and containing the fuel in the required state without leakage or environmental emissions (venting) during all routine and unscheduled operations and situations including idle periods.

Alternatively:

3.2.9 It shall be arranged for safe and suitable, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. 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 render the essential machinery or 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.

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

4 GENERAL REQUIREMENTS

4.1 Goal

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

4.2 Risk assessment

4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of gas-fuel or 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 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

4.3.1 An explosion in any space containing any potential sources of release[6] 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;

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

.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 fire-fighting equipment located outside the explosion-damaged space; or

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

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

PART A-1

SPECIFIC REQUIREMENTS FOR SHIPS USING NATURAL GAS AS FUEL

5 SHIP DESIGN AND ARRANGEMENT

5.1 Goal

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

5.2 Functional requirements

5.2.1 This chapter is related to functional requirements 3.2.1, 3.2.2, 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12, 3.2.13, 3.2.14, 3.2.15 and 3.2.17 of this Code. In particular the following apply:

.1 The fuel tank shall be sufficiently protected against the effect of external damage caused by collision, grounding, fire or other possible operational damage causes.

.2 Fuel containment systems, fuel piping and other fuel release sources shall be so located and arranged that released gas are lead to safe locations [in the open air].

.3 The access or other openings to spaces containing fuel release sources 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 the remaining power for propulsion and power generation after any gas leakage with following safety actions shall be sufficient for maintaining maneuverability and for providing power for essential services.
(Keep in 5.2. Move to 9.2. Move to 10.2.)

.6 The probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery shall be minimized.

5.3 General requirements

5.3.1 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."

5.3.2 Fuel storage tanks shall be protected against mechanical damage.

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

[5.3.4 The fuel storage tank(s) [if located in enclosed spaces] shall be protected from external damage caused by collision or grounding in the following way:

5.3.4.1 The fuel storage tank(s) shall be placed as close as possible to the centreline of the ship:

.1 minimum, [the lesser of B/5 and 11.5 m] from the ship side at right angles to the centreline at the level of the summer load line;

.2 [minimum, [the lesser of B/15 and 2 m] from the moulded line of the bottom shell plating at centreline; and

.3 not less than 760 mm from the shell plating.]

[5.3.5 For ships other than passenger ships [and multihulls], a tank location closer than B/5 from the ship side may be accepted and shall be taken as:

(Note: Limitations to be inserted based in input from SLF.)]

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

.1 at temperatures below minus 10ºC, hold spaces shall be segregated from the sea by a double bottom; and

.2 at temperatures below minus 55ºC, the ship shall also have a longitudinal bulkhead forming side tanks.]

(Note: Deletion of 5.3.6 supported however should consider if these requirements for double bottom and longitudinal bulkheads should be included in 6.4.3 and 6.4.4.)

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 release devices and ESD arrangements.

5.5 Requirements 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 8.6.

5.6 Requirements for ESD-protected machinery spaces

5.6.1 ESD protection is 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:

- Gas detector
- Shut of valve
- Redundancy
- Efficient ventilation
- Inerting measures

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 non-explosion protected equipment or installations shall be fitted, as outlined in 15.7 and 15.9.

(Note: It is commented that the term explosion protected is not defined in any international standard. Should we use ex-protected?

5.6.4 Distribution of engines between the different machinery spaces shall be such that in the case of shutdown of fuel supply to any one machinery space it is possible to maintain sufficient power for manoeuvrability and for essential power supply for sea going services.

5.7 Requirements for location and protection of fuel piping

5.7.1 Gas pipes shall not be located less than 760 mm from the ship's side.

[5.7.2 Gas fuel piping, whether single or double walled, shall not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations unless the gas piping is double walled and led through a dedicated duct.
The routeing of the piping shall take into account potential hazards due to mechanical damage.]

5.7.3 Gas 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 Fuel piping in ESD protected machinery spaces shall be protected against mechanical damage.

5.8 Requirements for machinery space design

5.8.1 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.

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

5.8.3 The ventilation system of ESD-protected machinery spaces shall be arranged in accordance with 13.5.2.

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

5.9 Requirements 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 liquid gas fuel is carried in a fuel containment system not requiring a secondary barrier, suitable drainage arrangements for the fuel storage hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.

5.9.3 Where there is 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.

5.9.4 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 Requirements 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 gas.

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 safety analysis can be handled.

5.11 Requirements for arrangement of entrances and other openings

5.11.1 Direct access shall not be permitted from a non-hazardous space to a hazardous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of chapter 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 air lock which complies with the requirements of chapter 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 air lock which complies with the requirements of chapter 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 open deck, sealing arrangements shall ensure that leakages of inert gas to adjacent spaces are prevented.

5.12 Requirements for air locks

5.12.1 An air lock is a space enclosed by gastight [steel] 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 Line, 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 Air locks shall be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.

5.12.2 bis The air lock has to be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the air lock. The events shall be evaluated in the risk analysis according to 4.2.1.

5.12.3 Air locks 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. Air locks shall not be used for other purposes, for instance as store rooms.

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

5.12.5 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.

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 under pressure in the hazardous space access to the space is to be restricted until the ventilation has been re-instated. 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.

5.12.8 Electrical equipment which is not of the certified safe type for propulsion, power generation, manoeuvring, anchoring and mooring equipment as well as the emergency fire pumps shall not be located in spaces to be protected by air-locks.

6 FUEL CONTAINMENT SYSTEM

6.1 Goal

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

6.2 Functional requirements

6.2.1 This chapter relates to functional requirements 3.2.1, 3.2.2, 3.2.5, 3.2.8, 3.2.9, 3.2.10, 3.2.11, 3.2.12, 3.2.13, 3.2.14, 3.2.15, 3.2.16 and 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 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 the remaining power for propulsion and power generation after any gas leakage shall be sufficient for maintaining manoeuvrability and for providing power for essential services. (Proposed moved to 9.3)

.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 chapter 7 of this Code.

6.3 General requirements

6.3.1 Natural gas in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 10 bar g.

6.3.2 The Maximum Allowable Working Pressure (MAWP) of the gas tank shall not exceed 90 per cent 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 shut down systems.

6.3.8*bis* The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk.
(Note: To be moved to 11.4.

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 gas and vent fuel storage tanks with gas piping systems. Proper 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 gas pipes. See detailed requirements in chapter 6.10.

6.4 Liquefied gas fuel containment

6.4.1 General

6.4.1.1 The risk assessment required in section 4.2 shall include evaluation of the vessel'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.

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7 IACS Rec.034 is referred.

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 7.4.1.2.

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 6.7.3.1. 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 containment. The design shall take into account proper combinations of the following loads:

- Internal pressure;
- External pressure;
- Dynamic loads due to the motion of the ship in all loading conditions;
- Thermal loads;
- Sloshing loads;
- Loads corresponding to ship deflections;
- Tank and liquefied gas fuel weight with the corresponding reaction in way of supports;
- Insulation weight;
- Loads in way of towers and other attachments; and
- 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 provide the indicated response to each of the following accident design conditions (accidental or abnormal events), addressed in this Code:

- Collision – The liquefied gas fuel containment system shall withstand the collision loads specified in 6.4.9.5.1 without deformation likely to endanger the tank and its supporting structure.

- Fire – The liquefied gas fuel containment systems shall sustain without rupture the rise in internal pressure specified in 7.4 under the fire scenarios envisaged therein.

- Flooded compartment causing buoyancy on tank – the anti-flotation arrangements shall sustain the upward force, specified in 6.4.9.5.2 and there should be no endangering plastic deformation to the fuel containment system and the hull.

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 or its Recognized Organization. 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.

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.

6.4.1.10 Maintenance and repair procedures shall include considerations with respect to the tank location and adjacent spaces (see chapter 5).

6.4.2 Liquefied gas fuel containment safety principles

6.4.2.1 The containment systems shall be provided with a full 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 the requirements of 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 capable of safely handling and disposing of the leakages.

The arrangements shall comply with the following requirements:

.1 Failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) 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 The structural failure/leakage probability level shall be evaluated to validate the design without secondary barrier.

6.4.2.6 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

6.4.3.1 Secondary barriers in relation to the tank types defined in 6.4.15.1 to 6.4.15.4 shall be provided in accordance with the following table.

Fuel temperature at atmospheric pressure	-10°C and above	Below -10°C down to -55°C	Below -55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Membrane Independent Type A Type B Type C		Complete secondary barrier Complete secondary barrier Partial secondary barrier No secondary barrier required	

6.4.4 Design of secondary barriers

6.4.4.1 Where the liquefied gas fuel temperature at atmospheric pressure is not below minus 55°C, the hull structure may be designed as a secondary barrier based on the following:

.1 the hull material shall be suitable for the liquefied gas fuel temperature at atmospheric pressure as required by 6.4.18.1.4; and

.2 the design shall be such that this temperature will not result in unacceptable hull stresses.

The location of a containment system using hull structure as secondary barrier shall be specially considered in conjunction with surrounding spaces.

6.4.4.2 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;

.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 or its Recognized Organization; and

.5 The methods required in 6.4.4.2.4 shall be approved by the Administration or its Recognized Organization 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 point 1 above.

.3 Scaling factors to be used 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

6.4.5.1 Partial secondary barriers as permitted in 6.4.2.3 shall be a small leak protection system and meet all the requirements in 6.4.4.2.

The partial secondary barrier 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 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 6.4.9.2-6.4.9.5, 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, N_2 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 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 the requirements in 6.4.10, 6.4.11 and 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.

6.4.9.2.2 Permanent external loads

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

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:

- Internal pressure
- External pressure
- Thermally induced loads
- Vibration
- Interaction loads
- Loads associated with construction and installation
- Test loads
- Static heel loads
- Weight of liquefied gas fuel
- Sloshing
- Wave impacts and green sea effect for tanks installed on open deck
- Wind impact as relevant

6.4.9.3.3.1 Internal pressure

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

i) Lower values of ambient temperature may be accepted by the Recognized Organization for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

ii) For ships on voyages of restricted duration, P_o 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 6.4.15.1 to 6.4.15.4, for the various tank types, a vapour pressure P_h higher than P_o may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.

.4 Pressure used for determining the internal pressure given in 6.4.12.1.4. shall be:

- (Pgd)max is the associated liquid pressure determined using the maximum design accelerations.
- (Pgd site)max is the associated liquid pressure determined using site specific accelerations
- Peq should be the greater of Peq1 and Peq2 calculated as follows:
- Peq1 = Po+(Pgd)max (MPa) Peq2 = Ph+(Pgd site)max (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 6.4.13.1. The value of internal liquid pressure Pgd resulting from combined effects of gravity and dynamic accelerations shall be calculated as follows:

$P_{gd} = \alpha_\beta Z_\beta(\rho/(1.02x10^5))$ (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 4.1)*

*Note 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 b direction (see figure 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:

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

where:

Vt = tank volume without any domes
FL = filling limit according to chapter 15
ρ = maximum liquefied gas fuel density (kg/m3) at the design temperature.

The direction that gives the maximum value (Pgd)max of Pgd 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.

6.4.9.3.3.2 External pressure

6.4.9.3.3.2.1 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 6.2.

6.4.9.3.3.4 Vibration

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

6.4.9.3.3.5 Interaction loads

6.4.9.3.3.5.1 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

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

6.4.9.3.3.7 Test loads

6.4.9.3.3.7.1 Account shall be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in 6.4.20 to 6.4.23.

6.4.9.3.3.8 *Static heel loads*

6.4.9.3.3.8.1 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

6.4.9.3.3.9.1 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.
(Note: move to definition?)

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:

- vertical acceleration: motion accelerations of heave, pitch and, possibly roll (normal to the ship base)
- transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll
- 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 Recognized Organization.

[Guidance formulae for acceleration components are given in MSC resolution MSC.[...].[(...)] "The Use of Limit State Methodologies in the Design of Containment Systems of Novel Configuration", as may be amended by the Organization."]

Ships for restricted service may be given special consideration.

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 by means of special tests and calculations covering 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 vessels 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

The collision load shall be determined based on the fuel containment system under fully loaded condition.

Ship length (L)	Design acceleration, a
L>100 m	0,5 g
60 < L <= 100 m	a = 2-[(3/80)(L-60)]
L<60 m	2g

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

6.4.9.5.2 Loads due to flooding on ship

For independent tanks and membrane tanks, loads caused by the buoyancy of a fully submerged empty tank or flooded compartment up to main deck, whichever is worst, shall be considered in the design of the fuel containment system, anti-flotation chocks and the supporting hull 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 6.4.15.1 to 6.4.15.4, 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 6.4.15.1 to 6.4.15.4, an alternative design methodology such as the Load Resistance Factor Design (LRFD) can be used to ensure that the overall level of safety provided for in this chapter is maintained.

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 and 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:

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

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

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

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

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

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

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ = static stresses
$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ = 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 6.4.16.2.

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 Code provisions:

.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.

Rm = specified minimum tensile strength at room temperature (N/mm2).

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 Re 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.

.2 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 Recognized Organization, account may be taken of the enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are based shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases for Fuel provided for in 1.5.

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

.5 Allowable stresses for materials other than those covered by chapter 6.3 shall be subject to approval by the Recognized Organization 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:

$$\sum_{i=1}^{I} \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_w$$

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, normally taken as 1000. Loading and unloading cycles include a complete pressure and thermal cycle.*
$N_{Loading}$ = *number of cycles to fracture for the fatigue loads due to loading and unloading.*
C_w = *maximum allowable cumulative fatigue damage ratio*

The fatigue damage 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 C_w 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 Recognized Organization.

.6 Where the size of the secondary barrier is reduced, as is provided for in 6.4.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

- Crack propagation paths in the structure, where necessitated by 6.4.12.2.7 to 6.4.12.2.9, as applicable
- Crack growth rate
- The time required for a crack to propagate to cause a leakage from the tank
- The size and shape of through thickness cracks
- The time required for detectable cracks to reach a critical state.

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

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 6.3 at the end of this chapter. 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 Recognized Organization.

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 requirements 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 should be applied as a minimum;

Cw 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.

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.
(Note: Move to definitions?)

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

To ensure that the liquefied gas fuel containment system, primary and secondary barriers, the thermal insulation, adjacent ship structure and other materials in the liquefied gas fuel containment system are constructed from materials of suitable properties for the conditions they will experience, both in normal service and in the event of failure of the primary barrier where applicable.
(Note: Consider the wording.)

6.4.13.1.1 Materials forming ship structure

6.4.13.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the liquefied gas fuel temperature is below minus 10°C. 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 item 1, 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 6.4.18.3.6 and 6.4.18.3.7 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 No credit shall be given for any means of heating, except as described in 6.4.13.1.1.4.

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

The ambient temperatures used in the design, described in 6.4.18.1.1, shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases for Fuel.

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 and that do not form the secondary barrier, shall also be in accordance with *table 5.5*. 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 The hull material forming the secondary barrier shall be in accordance with *table 7.2*. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by *table 7.2* shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

6.4.13.1.1.4 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, 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 6.13.1.1.2 and 6.4.13.1.1.3 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 6.13.1.1.4.2, for longitudinal bulkhead between liquid 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 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.

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

.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 6.4.13.1.1.4.1 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 or recognized organization acting on its behalf.

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, 7.5

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 Recognized Organization 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[9], 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
.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.

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9 Ref. section 7.4.16

6.4.4.13.2.6 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.

6.413.3.2 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:

- compatibility with the liquefied gas fuels
- solubility in the liquefied gas fuel
- absorption of the liquefied gas fuel
- shrinkage
- ageing
- closed cell content
- density
- mechanical properties, to the extent that they are subjected to liquefied gas fuel and other loading effects, thermal expansion and contraction
- abrasion
- cohesion
- thermal conductivity
- resistance to vibrations
- resistance to fire and flame spread
- 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 is to have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

6.4.13.3.5 Thermal insulation that does not meet recognized standards for fire resistance may be used in 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

To define suitable construction processes and test procedures in order to ensure as far as reasonably practical that the liquefied gas fuel containment system will perform satisfactorily in service in accordance with the assumptions made at the design stage.
(Note: Consider the wording.)

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. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure.

.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 Recognized Organization. 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.

6.4.14.1.3 Where applicable, all the construction processes and testing, except that specified in 6.4.14.3 shall be done in accordance with the applicable provisions of chapter 17.

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 a Recognized Organization. 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 If the liquefied gas fuel temperature at atmospheric pressure is below -10°C, 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 requirements of 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 7.4.14. These loads need not be combined with each other or with environmental loads.

6.4.15.1.2.4 For vacuum insulated tanks special attention shall be made to the strength of the support design and special considerations shall be made to the support design between inner and outer shell.

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 Recognized Organization. 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 a Recognized Organization for deep tanks taking into account the internal pressure as indicated in 7.4.9.3.3.1 and any corrosion allowance required by 6.4.1.5.

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 6.4.1.4.3 and 6.4.14, 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_o shall be less than 0.07 MPa.

6.4.15.2.1.2 If the liquefied gas fuel temperature at atmospheric pressure is below minus 10°C, a partial secondary barrier with a protection system is required as defined in 6.4.2. 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:

- Plastic deformation
- buckling
- fatigue failure
- 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:

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

where:

σ_m	=	equivalent primary general membrane stress
σ_L	=	equivalent primary local membrane stress
σ_b	=	equivalent primary bending stress
σ_g	=	equivalent secondary stress
f	=	the lesser of (R_m / A) or (R_e / B)
F	=	the lesser of (R_m / C) or (R_e / D)

with R_m and R_e as defined in 6.4.17.1.3. With regard to the stresses σ_m, σ_L and σ_b see also the definition of stress categories in MSC resolution MSC.[...].[(...)] "The Use of Limit State Methodologies in the Design of Containment Systems of Novel Configuration", as may be

amended by the Organisation." The values A and B, shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases for Fuel and 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:

Nickel steels and carbon-manganese steels the lesser of:
R_m / 2 or R_e /1.2

Austenitic steels the lesser of:
R_m/2.5 or R_e/1.2

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

6.4.15.2.3.2.1 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 should 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 6.4.1.4.3 and 6.4.9.5, 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 6.4.15.2.3.2, modified as appropriate, taking into account their lower probability of occurrence.

6.4.15.2.3.5 Marking

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

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:

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

where:

$$A = 0.00185((\sigma_m / \Delta\sigma_A))^2$$

with

σ_m = design primary membrane stress

$\Delta\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$)
55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel
25 N/mm^2 for aluminium alloy (5083-0)

C = a characteristic tank dimension to be taken as the greatest of the following:
h, 0.75b or 0.45l
with
h = height of tank (dimension in ship's vertical direction) (m)
b = width of tank (dimension in ship's transverse direction) (m)
ℓ = length of tank (dimension in ship's longitudinal direction) (m)
ρr = the relative density of the cargo (ρr = 1 for fresh water) at the design temperature.

When a specified design life of the tank is longer than 10^8 wave encounters $\Delta\sigma_A$ shall be modified to give equivalent crack propagation corresponding to the design life.

6.4.15.3.2 Shell thickness

6.4.15.3.2.1

.1 For pressure vessels, the thickness calculated according to 6.4.22.2.4 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.

.3 The welded joint efficiency factor to be used in the calculation according to 6.4.22.2.4 shall be 0.95 when the inspection and the non-destructive testing referred to in 6.5.6.5 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 Recognized Organization may accept partial non-destructive examinations, but not less than those of 6.5.6.5, 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 should 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:

$P_e = P_1+P_2+P_3+P_4$ 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 should 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 6.4.12.1, 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 Recognized Organization.

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 6.4.22.2.4.

.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 6.4.11 – 6.4.14 shall be used, as applicable. Stresses in way of the supports shall be to a recognized standard acceptable to the Recognized Organization. In special cases a fatigue analysis may be required by the Recognized Organization.

.3 If required by the Recognized Organization, 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

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 and σ_b see also the definition of stress categories in 6.4.16.5. The values A and B shall be shown on the International [Certificate of Fitness for the Carriage of Liquefied Gases for fuel] and 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 Recognized Organization may require additional verification to check their compliance with 6.4.22.1.1, 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 6.4.1.4.3 and 6.4.9.5, 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 If the liquefied gas fuel temperature at atmospheric pressure is below -10°C a complete secondary barrier is required as defined in 6.4.3.1. The secondary barrier shall be designed according to 6.4.4.

6.4.15.4.1.4 The design vapour pressure P_o 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_o 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.

6.4.14.4.1.5.bis: The circulation of inert gas throughout the primary and the secondary insulation spaces, in accordance with 7.11.1 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:

- Tensile failure of membranes
- Compressive collapse of thermal insulation
- Thermal ageing
- Loss of attachment between thermal insulation and hull structure
- Loss of attachment of membranes to thermal insulation system
- Structural integrity of internal structures and their supports
- Failure of the supporting hull structure

2) Fatigue design events:

- Fatigue of membranes including joints and attachments to hull structure
- Fatigue cracking of thermal insulation
- Fatigue of internal structures and their supports
- Fatigue cracking of inner hull leading to ballast water ingress

3) Accident design events:

- Accidental mechanical damage (such as dropped objects inside the tank while in service)
- Accidental over pressurization of thermal insulation spaces
- Accidental vacuum in the tank
- 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, e.g. pump and its supporting structure as defined 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 requirements for deep tanks, taking into account the internal pressure as indicated in 6.4.9.3.3.1 and the specified appropriate requirements for sloshing load as defined in 6.4.9.4.1.4.

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 requirements depending on:

- The significance of the structural components with respect to structural integrity
- 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 requirements 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 requirements 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 and design conditions specified in 6.4.1.4.3 and 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 Cargo containment systems that are of a novel configuration that cannot be designed using sections 6.4.14 and 6.4.15.1 to 6.4.15.4 shall be designed using this section, and section 6.4.1 to 6.4.8 and 6.4.9 of this chapter, and also section 6.4.10.-6.4.15 as applicable. Cargo containment system design according to this section is to be based on the principles of limit state design.

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

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:

- 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.

- Fatigue Limit States (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.

- 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 limit state design shall comply with MSC resolution MSC.[...].[(...)] "The Use of Limit State Methodologies in the Design of Containment Systems of Novel Configuration", as may be amended by the Organisation."

6.5 [Non permanently fixed] [Portable] tanks [for liquefied gas fuel]

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

6.5.2 Portable gas fuel tanks shall be located in dedicated areas fitted with:

- mechanical protection of the tanks depending on location and cargo operations
- if located on open deck: spill protection and water spray systems for cooling
- if located in an enclosed space: the space is to be considered as a tank connection space

6.5.3 Portable gas 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 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 for liquefied gas shall be connected to a fixed venting system.

6.5.8 Control and monitoring systems for portable gas fuel tanks shall be integrated in the ship's gas control and monitoring system. Safety system for portable gas fuel tanks shall be integrated in the ship's gas safety system (e.g. shut-down 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,

- with the exception of the pressure relief system in 6.5.6 each portable tank shall be capable of being isolated at any time; and
- isolation of one tank shall not impair the availability of the remaining portable tanks; and
- the tank shall not exceed its filling limits as given in 6.8.

6.6 Compressed gas containment system

6.6.1 The storage tanks to be used for compressed gas should be certified and approved by the Administration or its Recognized Organization.

6.6.2 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 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 compressed gas 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 compressed gas 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 compressed gas storage. Special consideration should be given to the extinguishing of jet-fires.

6.7 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 7.9 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 can not be excluded:

1. 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 can not enter safe areas.

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

6.7.2.3 Interbarrier spaces shall be provided with pressure relief devices.[10] 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 requirements apply to PRVs fitted to pressure relief systems:

.1 PRVs on liquefied gas 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;

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[10] IACS Unified Interpretation GC9 titled '*Guidance for sizing pressure relief systems for interbarrier spaces* 1988'.

.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 are to be of suitably robust construction to prevent damage.

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

.1 Procedures are to be provided and included in the operation manual (refer to chapter 17).

.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.

.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.

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 gas safe spaces; and

.2 exhaust outlet from machinery installations.

6.7.2.9 All other fuel gas vent outlets shall 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 liquid fuel tank. PRVs shall be positioned on the liquid fuel tank so that they will remain in the vapour phase at the filling limit (FL) as defined in 7.5, under conditions of 15° list and 0.015L trim, where L is defined in 2.2.

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:

$Q = FGA^{0.82}$ (m3/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);
F = 0.1 for membrane and semi-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
$G = 12.4/ LD (ZT/M)^{1/2}$

with:

T = temperature in Kelvin at relieving conditions, i.e. 120 per cent 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 = (k(2/(k+1))^((k+1)/(k-1))) ^1/2

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 (m2), as for different tank types, as shown in figure 7.7.1.

.3 rollover effects caused by mixture of fuels with different compositions and densities as applicable.

6.7.3.1.2 For vacuum insulated tanks in hold spaces and for tanks in hold spaces separated from potential fire loads by coffer dams or surrounded by ship spaces with no fire load the following applies:

If the pressure relief valves have to be sized for fire loads the fire factors according may be reduced to the following values:

F=0.5 to F=0.25
F=0.2 to F=0.1

The minimum fire factor is F=0.1

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

$$Mair = Q * \rho_{air} \text{ (kg/s)}$$

where:

Density of air (ρ_{air}) = 1.293 kg/m3 (air at 273.15 K, 0.1013 MPa).

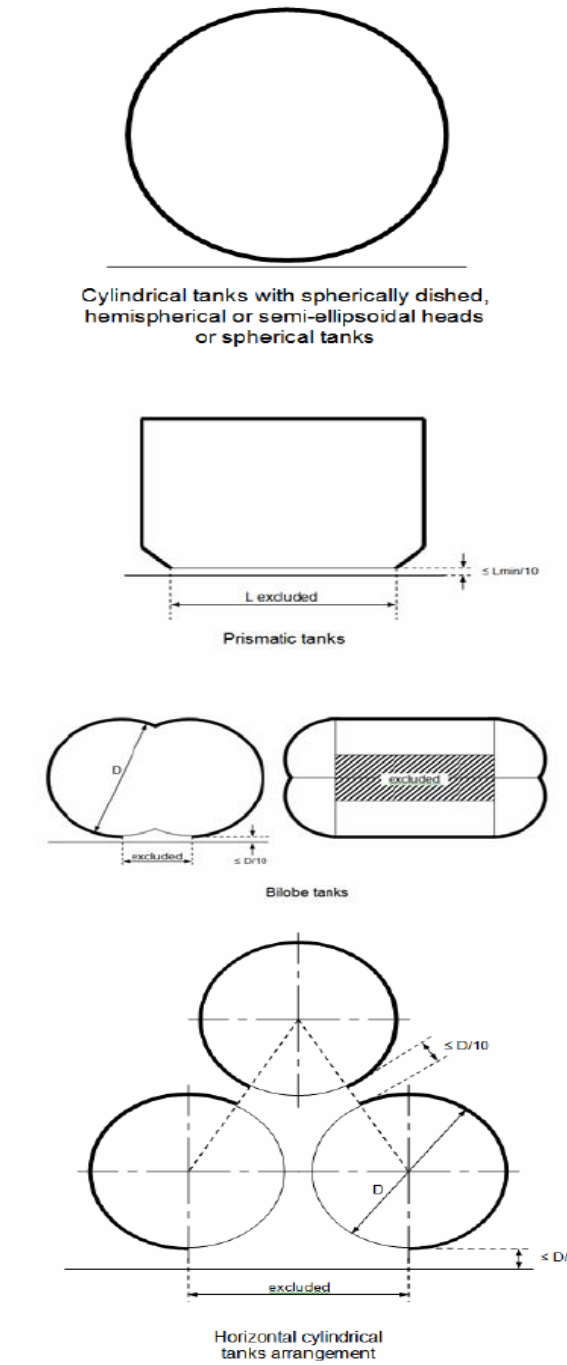
Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks
≤ Lmin/10
L excluded
Prismatic tanks
D
excluded
≤ D/10
excluded
Bilobe tanks
≤ D/10
D
≤ D/10
excluded
Horizontal cylindrical tanks arrangement

Figure 6.7.1

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 6.7.3.1.3.

6.7.3.2.2 The pressure losses shall not exceed the values permitted by the manufacturer. If no data from the manufacturer is available the values given in 6.7.3.2.3 shall be used.

6.7.3.2.3

- spring loaded safety valves without balanced bellows: 3% of MARVS upstream, 10% of MARVS downstream
- spring loaded safety valves with balanced bellows: 3% of MARVS upstream, 30% of MARVS downstream
- pilot operated safety valves: 3% upstream if the sensing line is not located at the top of the tank; 50% downstream.

(Note, see IGC for drafting purposes)

6.7.3.3 Upstream pressure losses

6.7.3.3.1 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 6.7.3.1.3 at 1.2 MARVS on all vapor flow.

6.7.3.3.2 Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.

6.7.3.3.3 Pressure losses in remotely sensed pilot lines should be considered for flowing type pilots.

6.7.3.4 Downstream pressure losses

6.7.3.4.1 Where common vent headers and vent masts are fitted, calculations are to include flow from all attached PRVs.

6.7.3.4.2 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 inter-connections that join other tanks, shall not exceed the values listed in 6.7.3.2.2.

6.7.3.4.3 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 Filling limit for liquefied gas fuel tanks

6.8.1 Storage tanks for liquefied gas shall not be filled to more than 98% full at the reference temperature, where the reference temperature means the temperature corresponding to the vapour pressure of the fuel at the set pressure of the pressure relief valves.

A filling limit curve for actual fuel filling temperatures shall be prepared from the following formula:

$LL = FL\ \rho_R/\rho_L$

where:

LL = loading limit, maximum allowable liquid volume relative to the tank volume to which the tank may be loaded, expressed in per cent;
FL = filling limit 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 However, in cases where the tank insulation and tank location make 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%. This will be also be valid in case 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 filling limit as calculated in 6.8.1 should be used.

6.9 Maintaining fuel storage condition

6.9.1 Control of tank pressure and temperature:

6.9.1.1 With the exception of fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, 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; and

.4 liquefied gas fuel cooling.

The method chosen shall be capable of maintaining tank pressure below the set pressure of the tank 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, as appropriate.

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 fuel tanks.

.2 an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

.3 a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks.

.4 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 has to be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard periods of slow steaming and/or no consumption from propulsion or other services of the vessel has to be considered.

6.9.5 Compatibility

6.9.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel must 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 must 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 gas 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 Atmospheric control within the fuel storage system

(Note: Consider if this should be a separate chapter)

6.10.1 A piping system shall be arranged to enable each fuel storage tank to be safely gas-freed, and to be safely filled with fuel gas 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 tanks may be provided externally to the ship.

6.11 Atmosphere control within hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases 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 cargo 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 Environmental control of spaces surrounding type C independent tanks

6.12.1 Spaces surrounding 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 fuel tanks where condensation and icing due to cold surfaces is an issue.

6.13 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 gas safe 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 gas fuel system. These valves shall be located outside non-hazardous spaces.

6.13.3 Where the connections to the gas 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 Inert gas production on board

6.14.1 The equipment shall be capable of producing dry inert gas with oxygen content at no time greater than 5 per cent by volume [with a dew point of minus 45 ^{o}C]. 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 per cent oxygen content by volume.
(Note: Clarify where the dew point is applicable and inerting versus purging in the various paagraphs)

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.
(Note: Consider liquid nitrogen implicaions)

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
- 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 gas 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 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10, of this Code. 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 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 Requirements 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.[11]

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 liquid or gas, 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.
(Note: Proposed moved to 9.5.2 bis.)

7.3.2 Wall thickness

7.3.2.1 The minimum wall thickness shall be calculated as follows:

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

where:

t_o = theoretical thickness

$t_o = PD/(20Ke + P)$ (mm)

with:

P = design pressure (bar) referred to in 7.3.3.

D = outside diameter (mm)

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

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

b = 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:

$b = Dt_0/2.5r$ (mm)

with:

r = mean radius of the bend (mm)

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

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 requirements. This allowance shall be consistent with the expected life of the piping.

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[12][13]:

.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 10 bar except for open ended lines where it is not to be less than 5 bar.

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 5.3.2.1 shall be the lower of the following values:

Rm/2.7 or Re/1.8

Where:

Rm = specified minimum tensile strength at room temperature (N/mm²)

Re = 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

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12 Lower values of ambient temperature regarding design condition in 5.3.3.1.1 may be accepted by the Administration or its recognized organization for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required

13 For ships on voyages of restricted duration, P_o 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 "Application of Amendments to Gas Carrier Codes Concerning Type C Tank Loading Limits" (SIGTTO/IACS).

over that required by 7.3.1 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 or its Recognized Organization.

7.3.4.4 High pressure gas piping systems shall have sufficient constructive strength. This shall be confirmed by carrying out stress analysis and taking into account:

- stresses due to the weight of the piping system
- acceleration loads when significant
- 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 gas 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 gas 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.
(Note: Consider relocation)

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 -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 10 bar 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.

.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.

.3 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

.1 Where bellows and expansion joints are provided in accordance with 7.3.6.1 the following requirements 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.

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

7.3.6.4.4 Other connections

.1 Piping connections shall be joined in accordance with 7.3.6.4.1-7.3.6.4.3 but for other exceptional cases the Administration or its Recognized Organization may consider alternative arrangements.

7.4 Requirements for materials

7.4.1 Metallic materials

7.4.1.1 Materials for fuel containment and piping systems shall comply with the minimum requirements 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 -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 5.4.13.1.1.2.

Table 7.1

PLATES, PIPES (SEAMLESS AND WELDED)[See note 1 and 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 [See note 4]		
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
Sampling frequency		
◆ Plates	Each "piece" to be tested	
◆ Sections and forgings	Each "batch" to be tested.	
Mechanical properties		
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [see note 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)
	$t \leq 20$	0
	$20 < t \leq 40$ [See note 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 Recognized Organization.
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 Recognized Organization.
4. A controlled rolling procedure or TMCP may be used as an alternative.
5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by a Recognized Organization. For these materials, particular attention should be given to the hardness of the welded and heat affected zones.

Table 7.2

PLATES, SECTIONS AND FORGINGS [See note 1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO - 55°C
Maximum thickness 25 mm [See note 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. See note 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 [See note 4]

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Sampling frequency	
◆ Plates	Each 'piece' to be tested
◆ Sections and forgings	Each 'batch' to be tested
Mechanical properties	
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [See note 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 requirements 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 Recognized Organization

   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 TMCP may be used as an alternative.
5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by a Recognized Organization. For these materials, particular attention should 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 [see note 1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW -55°C AND DOWN TO -165°C [see note 2]
Maximum thickness 25 mm [see note 3 and 4]

Minimum design temp. (°C)	Chemical composition [see note 5] and heat treatment	Impact test temp. (°C)
-60	1,5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [see note 6]	-65
-65	2,25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [see notes 6 and 7]	-70
-90	3,5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [see notes 6 and 7]	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered [see notes 6, 7 and 8]	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered [see notes 6]	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated [see note 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 REQUIREMENTS	
Sampling frequency	
◆ Plates	Each 'piece' to be tested
◆ Sections and forgings	Each 'batch' to be tested
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J

Notes

1 The impact test required for forgings used in critical applications shall be subject to special consideration by the Administration.

2 The requirements 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)
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	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 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) [See note 1], FORGINGS [See note 2] AND CASTINGS [See note 2] FOR FUEL AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO -165°C [See note 3]
Maximum thickness 25 mm

Minimum design temp.(°C)	Chemical composition [See note 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. [see notes 6]	See note 4	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered. [see notes 6]	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered. [see notes 6]	-95	34
-165	9% nickel steel [see note 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. [see note 8]	-196	41
	Aluminium alloys; such as type 5083 annealed		Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Sampling frequency

- Each 'batch' to be tested.

Toughness (Charpy V-notch test)

- Impact test: Longitudinal test pieces

Notes

1 The use of longitudinally or spirally welded pipes shall be specially approved by the Administration.
2 The requirements for forgings and castings may be subject to special consideration by the Administration.
3 The requirements 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 ?? AND ??

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above [see note 1] -5 and above [see note 2]	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 5.2 except that the thickness limitation given in table 5.2 and in footnote 2 of that table does not apply.							

Notes

'x' means steel grade not to be used.

1. For the purpose of 5.4.13
2. For the purpose of 5.4.13

7.4.1.2 Material having a melting point below 925°C should not be used for piping outside the gas 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 requirements 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 gas pipes with liquid gas shall as a minimum fulfil the material requirements 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 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.8, 3.2.9, 3.2.10, 3.2.11, 3.2.13, 3.2.14, 3.2.15, 3.2.16 and 3.2.17 of this Code. 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.

8.2.1.2 The vessel shall not connect to any facility or barge which does not meet an applicable and appropriate safety standard.
(Note: should be addressed in an operational chapter)

8.3 Requirements for bunkering station

8.3.1 General requirements

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 safety analysis.

8.3.1.3 Connections and piping shall be so positioned and arranged that any damage to the gas piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.

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

8.3.1.6 Suitable means should be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines. Liquid is to be discharged to the fuel tanks or other suitable location.

8.3.1.7 The surrounding hull or deck structures shall not be exposed to unacceptable cooling, in case of leakage of liquid gas.

8.3.1.8 For compressed gas 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

(Note: Check consistence with ISO TC 67/WG 10 if available in time)

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 Requirements 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 Requirements for bunkering system

8.5.1 For tanks not permanently installed in the vessel the connection of all necessary tank systems (piping, controls, safety system, relief system etc.) to the gas system of the vessel is part of the "bunkering" process and shall be finished prior to ship departure from the bunkering station. Connection of portable tanks during the sea voyage or manoeuvring is not permitted.

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

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

8.5.4 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.

8.5.5 Means shall be provided for draining any liquefied gas from the bunkering pipes upon completion of operation.

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

8.5.7 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.

[8.5.8 If the vessel intends to carry out cargo operations in parallel with bunkering. Vessel shall be fitted with an interlinked ESD-System to the bunker supply facility ensuring an efficient shut down of both operations in case of emergency.]

(Note: To be further discussed What about passenger ships?

8.5.9 If not demonstrated to be required at a higher value due to pressure surge considerations a default time of 5 seconds from the trigger of the alarm to full closure of the valve shall be adjusted.

8.5.10 Bunkering lines are not to pass through accommodation, service spaces or control stations. Where bunkering lines pass through other gas safe spaces, these are to comply with the requirements of 9.6.2 (i.e. enclosed in a double-walled piping or a ventilated gas-tight duct).

(Note: Need to make sure this is not in conflict with whatever we agree in 5.7.2 and 9.5.2)

9 FUEL SUPPLY TO CONSUMERS

9.1 Goal

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

9.2 Functional requirements

9.2.1 This chapter is related to functional requirements 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.8, 3.2.9, 3.2.10, 3.2.11, 3.2.13, 3.2.14, 3.2.15, 3.2.16 and 3.2.17 of this Code. In particular the following apply:

9.2.1.1 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.

9.2.1.2 The piping system for gas 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.

9.2.1.3 Fuel lines outside the machinery spaces shall be installed and protected so as to minimize the risk of injury to personnel in case of leakage.

9.3 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 gas tanks to the consumer, so that a leakage in one system does not lead to loss of propulsion and/or power to essential consumers.

9.3.2 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks [sized to meet the requirements of SOLAS chapter II-1/26.11]. The tanks should be located in separate compartments. [For type C tanks with separate tank connection spaces, the tanks may be located in the same compartment.]

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 Safety functions of gas supply system

9.4.1 Gas 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[14] which are not accessible shall be remotely operated. [Tank valves shall be automatically operated when the safety system required in 15.2.1.2 is activated.]

9.4.2 The main gas supply line to each engine or set of engines 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 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 shall automatically cut off the gas supply when activated by the safety system required in 15.2.1.2.]

Alternatively

9.4.2 It shall be possible to isolate the gas fuel supply to each individual space containing a gas consumer(s) with an individual master gas fuel valve, which is located [outside the engine-room]. It shall operate under the following circumstances:

.1 automatically by:

.1.1 gas detection within the space;

.1.2 leak detection in the annular space of a double walled space;

.1.3 loss of ventilation in the annular space of the double walled pipe;

.2 manually from within the space, and at least one remote location.

The isolation of gas fuel supply to a space shall not affect the gas supply to other spaces containing gas consumers.

9.4.3 The automatic master gas fuel valve shall 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 navigation bridge.

9.4.4 Each gas consuming equipment shall be provided with a set of "double block and bleed" valves. These valves shall be arranged as outlined in .1 or .2 (respectively shown as alternatives 1 and 2 in figure 1) [so that when the safety system required in 15.2.1.2 is activated this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically and]:

.1 the two [double block]shut-off valves of these 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 [shut-off] 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.

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

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 shut-down, 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 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.The examples are similar for low pressure systems.

(Note: the marking on the figures for "double block and bleed" is not very clear, considering that this function is separately required:
1) on the Master gas valve (9.4.2) to isolate the engine-room and
2) on the valve(s) at each consumer (9.4.4).)

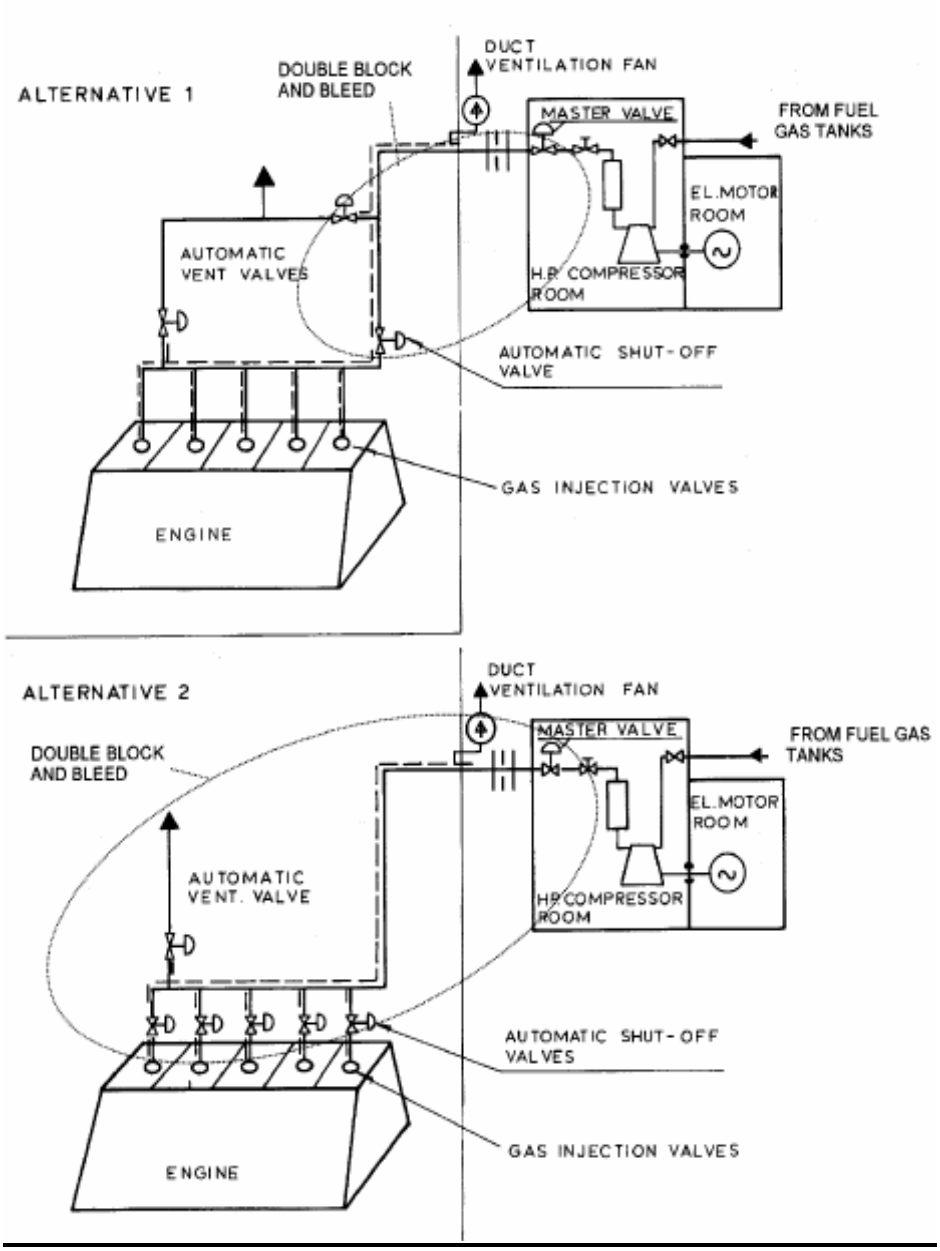

Figure 1
Alternative supply valve arrangements for high-pressure installations (single engine or separate master valve arrangement)

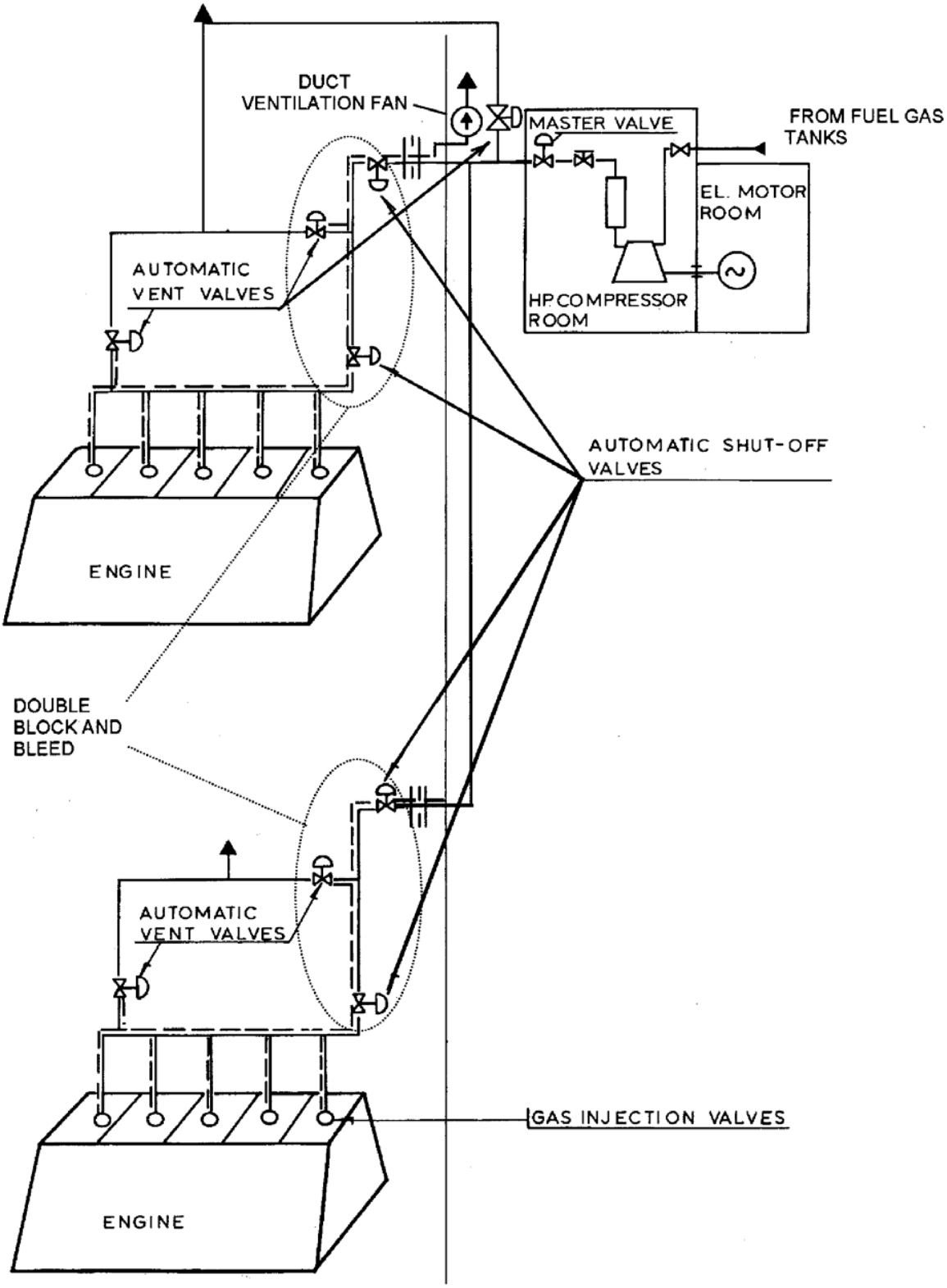

Figure 2
Alternative supply valve arrangements for high-pressure installations (multi-engine installation)

9.4.10 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[15]. 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.
(Note: No agreement on "high" and footnote)

9.5 Requirements for fuel distribution outside of machinery space

9.5.1 Where gas pipes pass through enclosed spaces in the ship, they shall be protected by a secondary barrier. This barrier can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in 15.8 shall be provided.

9.6 Requirements 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 A double wall design with the space between the pipes pressurized with inert gas at a pressure greater than the gas fuel pressure;]

.2 As an alternative to pressurized inert gas, the space between the concentric pipes may be pressurized with inert gas at a pressure lower than the gas fuel pressure provided that:

- A high pressure alarm shall be provided to indicate a leakage from the inner pipe
- A low pressure alarm shall be provided to detect leakage of inert gas
- The outer pipe shall be designed for the maximum service pressure of the inner pipe.]

Valves on the inert gas system (filling, purge) shall be designed for the maximum pressure in the inner pipe.

.3 Installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, and shall be arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation shall be in accordance with chapter 13 as applicable. [The ventilation shall always be in operation when there is fuel in the piping and the isolating valve shall close automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space, the ventilation outlet shall be in a safe location.] [For high pressure systems both ventilation inlets and outlets shall be in a safe location on open deck.]

.4 A double wall piping with vacuum in the outer pipe. The vacuum shall be monitored. Loss of vacuum shall lead to shut down and purging of the line. [Flanges in the vacuum piping located in enclosed spaces must be efficiently protected within a double duct or pipe.]

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15 The shutdown shall be time delayed to prevent shutdown due to transient load variations.

.5 A double wall design with the annular space between the inner and outer pipes continuously monitored for hydrocarbon presence. The master gas valve shall close automatically with the presence of gas detected in the space.]

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[16].

[9.6.3 Where the use of double ducting is not practicable at a gas consumer a hood or casing enclosing the consumer may be fitted in lieu. The hood or casing shall be equipped with mechanical exhaust ventilation complying with 9.6.1.3. The double pipe or duct within the machinery space may terminate at the boundary of the hood or casing.]

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

9.7.1 The pressure in the fuel supply system shall not exceed 10 bar.

9.7.2 The fuel supply lines shall have a design pressure not less than 10 bar.

9.8 Requirements 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 gas systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively for fuel gas piping systems with a working pressure greater than 10 bar, the design pressure of the outer 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.

(Note: JT effects sufficiently considered?)

9.8.2 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 [shall be taken as] [could be defined by] the critical pressure given by the following expression:

$$p = p0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

Where

p0= maximum working pressure of the inner pipe

16 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. (meaning is questioned)

k= Cp/Cv constant pressure specific heat divided by the constant volume specific heat

k = 1.31 for CH4

The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 (Rm/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.

9.8.3 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.

9.8.4 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.

9.9 Requirements for gas 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 pump 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:

- Environmental
- Shipboard vibrations and accelerations
- Effects of pitch, heave and roll motions, etc.
- 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 ENERGY CONVERTERS

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

10.2.1 This chapter is related to Functional requirements 3.2.1, [3.2.7], 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

10.2.1.1 The exhausts system shall be configured to prevent any accumulation of un-burnt gaseous fuel.

10.2.1.2 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.

10.2.1.3 The explosion venting shall be led away from where personnel may normally be present.

10.2.1.4 All energy converters shall have separate exhaust system.

10.3 Requirements 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 is to be carried out and reflected in the safety concept of the engine.

[10.3.1.3 If the gas supply is not changed-over to an alternative type, e.g. oil fuel, before stopping, the machinery including the exhaust system, gas compressor, gas system and supply lines up to the master valve shall be purged in order to discharge any residual gas which may be present.]
(Note: Kept in square brackets for further discussion)

10.3.1.4 Each engine other than two-stroke crosshead diesel engines shall be fitted with vent systems independent of other engines for crankcases and sumps.

10.3.1.5 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted [at] [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.

[10.3.1.6 The crankcase of a trunk piston type engines shall be fitted with a means of [manually] injecting inert gas.]
(Note: Include manually and independent arrangements for each gas-fuelled engine have some support)

10.3.1.7 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit shall be verified.

10.3.1.8 A means shall be provided to monitor and detect poor combustion or mis-firing 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 shut down. It shall be possible to manually over-ride the shut down system] [gas operation may be allowed provided that the gas supply to the concerned engine is shut-off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations].

10.3.1.9 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 un-burnt fuel mixture is purged away from the exhaust system shall be provided.

10.3.2 Requirements for dual fuel engines

10.3.2.1 In case of shut-off 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 shut down shall always be possible

10.3.2.3 In case of a normal stop or an emergency shut-down, 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 Requirements for gas-only engines

10.3.3.1 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 Requirements for multi-fuel engines

10.3.4.1 In case of shut-off 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 Requirements for boilers main and auxiliary

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] [with minimum] 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 pipe of each gas burner a manually operated shut-off 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 6.7.5 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 Requirements for gas turbines

10.5.1 The exhausts shall be appropriately configured to prevent any accumulation of un-burnt fuel gas.

10.5.2 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 non-hazardous location, away from personnel.

10.5.3 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 6.5, however a pressure above 10 bar in the gas supply piping may be accepted within this enclosure.

10.5.4 Gas detection systems and shut down functions shall be as outlined for ESD protected machinery spaces.

10.5.5 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 (2x100% capacity fans from different electrical circuits).

10.5.6 For other than single fuel gas turbines, an automatic system shall be fitted to change over easily and quickly from fuel gas operation to fuel oil operation [and vice-versa] with minimum fluctuation of the engine power.

10.5.7 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 shut down.

10.5.8 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.]

10.6 Requirements for fuel cells

(Note: Support for moving to separate section. Will be moved at a later stage.)

10.6.1 The design shall ensure that any single failure in active components of the fuel cell system shall not lead to loss of propulsion or auxiliary power for essential services.[17]

10.6.2 The arrangement of the fuel cell spaces shall be so that a necessary shut down due to a fuel or oxidant leakage cannot lead to loss of propulsion or auxiliary power for essential services.

10.6.3 If the power from the fuel cell is needed for restoration of power in a black out or dead ship situation, the recovery arrangements have to be documented and approved in each case.

10.6.4 Fuel cell spaces shall have as simple geometrical shape as possible. Fuel cell spaces where hydrogen may be present shall have no obstructing structures in the upper part and shall be arranged with a smooth ceiling sloping up towards the ventilation outlet. Support structure like girders and stiffeners shall be facing outwards.
Thin plate ceiling to cover support structure under the deck plating is not acceptable.
(Note: Some explanation from proponent would be helpful)

10.6.5 The presence of fuel release sources in a fuel cell space will decide if it is regarded as a hazardous or non hazardous space. There are two ways to make a fuel cell space non hazardous:

.1 All fuel pipes are enclosed in a gas tight double enclosure (duct or pipe) fulfilling the requirements in 10.4.

[17] The fuel cell is defined as an active component. Other active components are components for mechanical transfer of energy, e.g. pumps, fans, electric motors, generators, combustion engines and turbines. Heat exchangers, boilers, transformers, switchgear or cables are not considered to be active components.

.2 All FC fuel pipes that are not inside a double duct are fully welded and the ventilation rate in the space is sufficient to avoid gas concentration in the flammable range in all leakage scenarios, including pipe rupture. Valves in the fuel cell piping shall be leakage tested for the fuel used. In addition the fuel cell space is fitted with gas detection and an automatic shut down system as for ESD protected machinery spaces.[18][19]

10.6.6 Fuel cell stacks, fuel cell conditioning system (such as pre-heater, compressor, filter, reformer etc…) and gas storage system shall be located in spaces separated from each other and from other spaces. For fuel cell systems with aggregate power lower than 375 kW, the installation of the whole fuel cell system in the same compartment may be accepted by the Administration provided that suitable arrangements are made in order to prevent gas from reaching the fuel cell stacks in case of a leakage from the storage or conditioning system (e.g. screen or suitable enclosure with exhaust arrangement).
(Note: Some explanation from proponent would be helpful)

10.6.7 In general, the requirements set out in chapter 11 apply. The fire-extinguishing system shall be chosen according to the specific fuel cell type and shall not be limited to a water spray system.

11 FIRE SAFETY

11.1 Goal

11.1.1 The goal of this part 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

11.2.1 This chapter is related to functional requirements 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 in this Code.

11.3 General

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.

11.4 Requirements for fire protection

11.4.1 Fuel tank(s) located above [the bulkhead] deck shall be shielded with class A-60 insulation towards accommodation, machinery spaces and in way of escape routes. Tanks shall also be segregated from cargo in accordance with the requirements of the IMDG Code where the tanks are regarded as bulk packaging.

11.4.2 Any boundary of accommodation up to bridge windows, machinery spaces and cargo spaces facing gas fuel tanks on open deck shall have A-60 fire integrity and bridge windows A-0 (with fire risk from outside).

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18 If hydrogen valves are located in a space kept non hazardous in the above manner (2), [the valves should be leakage tested with hydrogen] [leakage tests shall be conducted with pressurized gas such as air or nitrogen containing at least 10 per cent helium or hydrogen]. For other fuels normal hydrostatic pressure testing with water as part of the product certification will be sufficient.

19 Compensators or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe are not accepted in FC fuel piping in a space kept gas safe in the above manner (2).

11.4.3 The fuel containments system boundaries and ventilation trunks to such spaces below the bulkhead deck should be constructed to class A-60 standard and cofferdam. The separation by means of a cofferdam shall be at least 900 mm. For the purpose of this regulation for type C tanks, the hold space may be considered as a cofferdam. 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 and a cofferdam is not required.

11.4.4 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.

11.4.5 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.

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

11.5 Requirements for fire main

11.5.1 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.

11.5.2 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.

11.6 Requirements for water spray system

11.6.1 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.

11.6.1*bis* 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.
(Note: It is proposed to have a general requirement for water spray system in 10.3 (now 5, but have no subsection on location and protection) and the details in chapter 11.)

11.6.2 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.

11.6.3 Stop valves shall be fitted in the spray water 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.

11.6.4 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.

11.6.5 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.

11.6.6 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.

11.6.7 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.

11.7 Requirements for dry chemical powder fire-extinguishing system

11.7.1 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.

11.7.2 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.

11.8 Requirements for fire detection and alarm system

11.8.1 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.

11.8.2 Smoke detectors alone shall not be considered sufficient for rapid detection of a fire.

12 EXPLOSION [PREVENTION] [PROTECTION] [AREA CLASSIFICATION]

12.1 Goal

12.1.1 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

12.2.1 This chapter is related to functional requirements 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.7, 3.2.8, 3.2.12, 3.2.13, 3.2.14 and 3.2.17 of this Code. In particular the following apply:

12.2.1.1 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 General requirements

12.3.1 Hazardous areas on open deck and other spaces not addressed in this chapter shall be decided based on a recognized standard[20]. 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[21].

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 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.[22] 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:

12.5.1.1 This zone includes, but is not limited to:

.1 the interiors of gas tanks, any pipework for pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.

12.5.2 Hazardous area zone 1[23]

12.5.2.1 This zone includes, but is not limited to:

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

21 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.

22 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.

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

.1 Tank connection spaces, fuel storage hold spaces[24] and interbarrier spaces.

.2 gas compressor room and or 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 gas tank outlet, gas or vapour outlet,[25] 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 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 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 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.

.9 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[26]

12.5.3.1 This zone includes, but is not limited to:

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

13 VENTILATION

13.1 Goal

13.1.1 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

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24 Fuel storage hold spaces for type C tanks are normally not considered as zone 1.

25 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.

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

13.2.1 This chapter is related to functional requirements 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12, 3.2.13, 3.2.14 and 3.2.17 of this Code.

13.3 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 motor is certified for the same hazard zone as the space served.

13.3.3 Design of ventilation fans serving spaces containing gas sources shall fulfil the following:

13.3.3.1 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 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.

13.3.3.2 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.

13.3.3.3 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 The ventilation inlet for the double wall piping or duct shall always be located in [open air], away from ignition sources. The inlet opening shall be fitted with a suitable wire mesh guard and protected from ingress of water.

13.3.7 The capacity of the ventilation for a pipe duct or 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.

13.3.8 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

13.3.9 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.

13.3.10 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.

13.3.11 Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an air-lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation shall be arranged according to the following requirements:

13.3.11.1 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.

13.3.11.2 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[27] shall be required.

13.3.12 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an air-lock 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.

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[27] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

13.4 Requirements 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 safety analysis.

13.4.2 Approved automatic fail-safe fire dampers shall be fitted in the ventilation trunk for tank connection space.

13.5 Requirements for machinery spaces

13.5.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems. 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.
(Note: Move last part to 13.9)

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.

13.5.2.bis [[For ESD protected machinery spaces] the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in the appropriate standard*.]

**Footnote reference to IEC 60092-10-1*

[13.5.3 The number and power of the ventilation fans 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.]

Or:

[13.5.3 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 Requirements for fuel preparation room, pump and compressor rooms

13.6.1 Fuel preparaton rooms, pump and compressor rooms shall be fitted with effective mechanical ventilation system of the under pressure 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, pump and compressor rooms shall be in operation when pumps or compressors are working.

13.6.4 When the space is dependent on ventilation for its area classification, the following shall apply:

13.6.4.1 During initial start-up and after the loss of ventilation, the space shall be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in the absence of ventilation. Warning notices to this effect shall be placed in an easily visible location near the control stand.

13.6.4.2 Operation of the ventilation shall be monitored.

13.6.4.3 In the event of failure of ventilation, the following shall apply:

.1 an audible and visual alarm shall be given at a manned location;

.2 immediate action shall be taken to restore ventilation; and

13.7 Bunkering station

[13.7.1 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.]
(Note: Deletion proposed based on 8.3.1.1.)

[13.7.2 When in accordance with 13.7.1 forced ventilation is fitted, a minimum ventilation rate of 30 air changes per h is required. Air changes shall be calculated using as reference volume the volume of the bunker station without following ventilation ducting and assuming that no equipment is installed.] (Note: Deletion proposed. No clear majority)

13.8 Ducts and double pipes

13.8.1 Ducts and double pipes containing gas 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.

14 ELECTRICAL INSTALLATIONS

14.1 Goal

14.1.1 The goal of this chapter is to provide for electrical installations that minimizes the risk of [fire and explosion from flammable products][ignition].

14.2 Functional requirements

14.2.1 This chapter is related to functional requirements 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, [3.2.11], 3.2.13, 3.2.16 and 3.2.17, [and 3.2.19] of this Code. In particular the following apply:

14.2.1.1 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 storage pressures and hull structure temperature within normal operating limits.

14.3 General requirements

14.3.1 Electrical installation 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 14.2.1.1 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 Submerged fuel gas pump motors and their supply cables may be fitted in fuel containment systems. Arrangements shall be made to alarm in low liquid level and automatically shut down the motors in the event of low-low liquid level. The automatic shut down may be accomplished by sensing low pump discharge pressure, low motor current, or low liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre. Fuel gas pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

(Note: It is proposed to keep only the last sentence here and move the rest to chapter 15.)

15 CONTROL, MONITORING AND SAFETY SYSTEMS

15.1 Goal

15.1.1 The goal with this chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other chapters of the code.

15.2 Functional requirements

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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.

15.2.1 This chapter is related to functional requirements [3.2.1, 3.2.11, 3.2.13, 3.2.14, 3.2.15, 3.2.17 and 3.2.19 and new proposals for chapter 3]. In particular the following apply:

15.2.1.1 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.

15.2.1.2 A gas safety system shall be arranged to close down the gas supply system automatically, upon failure in systems essential for the safety philosophy and upon fault conditions which may develop too fast for manual intervention.

15.2.1.2*bis* For ESD protected machinery configurations the safety system shall shut down gas supply upon gas leakage and in addition disconnect all non-safe type equipment in the machinery space.

15.2.1.3 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.

15.2.1.4 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.

15.2.1.5 Where two 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 General requirements

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 bilge well. Low temperature indication shall activate the safety system.

15.3.3 For tanks not permanently installed in the vessel a monitoring system has to be provided as for permanent installed tanks.

15.4 Requirements for bunkering and gas tank monitoring

(Note: consider temperature monitoring issue)

15.4.1 Level indicators for fuel tanks

.1 Each fuel tank shall be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the fuel tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the fuel tank and at temperatures within the fuel operating temperature range.

.2 Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

.3 Fuel tank liquid level gauges may be of the following types:

.1 indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering;

.2 closed devices, which do not penetrate the fuel tank, such as devices using radio-isotopes or ultrasonic devices;

15.4.2 Overflow control

.1 Each 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 tank from becoming liquid full.

.3 The position of the sensors in the tank shall be capable of being verified before commissioning. At first loading, testing of high level alarms shall be conducted by raising the cargo liquid level in the 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 18.6.2.

.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 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 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 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 For fuel tanks fitted with PRVs, which can be set at more than one set pressure in accordance with 8.2.7, high-pressure alarms shall be provided for each set pressure.
(Note: reference to the control station for location of alarms?)

15.4.7 Each fuel pump discharge line and each liquid and vapour fuel manifold shall be provided with at least one local pressure indicator.

15.4.8 Local-reading manifold pressure indicator shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

15.4.9 Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indicator.

15.4.10 At least one of the pressure indicators provided shall be capable of indicating throughout the operating pressure range.

15.5 Requirements 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 and tank level shall be monitored. Remotely controlled valves required by 9.5.5 and 11.6.6 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 shut-down shall be provided at the bunkering control location.

15.6 Requirements 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-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 required in 8.9.1 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 Requirements for gas engine monitoring

15.7.1 Additional to the instrumentation provided in accordance with SOLAS chapter II-1, Part C, 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 Requirements for gas detection

15.8.1 Permanently installed gas detectors shall be fitted in :

.1 the tank connection spaces
.2 in all ducts around gas pipes
.3 in machinery spaces containing gas piping, gas equipment or gas consumers
.4 compressor rooms and fuel preparation rooms

.5 other enclosed spaces containing gas piping or other gas equipment without ducting
.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and hold spaces of independent tanks other than type C
.7 air locks
.8 gas heating circuit expansion tanks
.9 motor rooms associated with the fuel systems
.10 At ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2.1.

15.8.2 In each ESD-protected machinery space, a 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].

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 Requirements for fire detection

15.9.1 Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage [fuel containments systems] are given in table 1 below.
(Note: It is proposed to add one more column to Table 1 entitled 'Ventilation Stop and Fire Damper Close, either automatic or simple action'.

15.10 Requirements 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.

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

15.11 Safety functions of gas supply systems

15.11.1 The total loss of ventilation in a machinery space for a single fuelled gas system shall, 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 shall start. When the second engine is connected to bus-bar, the first engine shall be shutdown automatically;

.2 for a direct propulsion system with more than one machinery space: The engine in the room with defect ventilation shall be manually shutdown, if at least 40% propulsion power is still available after such a shutdown; and

.3 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 shall close automatically provided the other gas supply unit is ready to deliver.

15.11.2 If the gas supply is shut off due to activation of an automatic valve, the gas 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 shut-off valves in the gas supply lines.

15.11.3 If a gas leak leading to a gas supply shutdown occurs, the gas 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.

15.11.4 A signboard shall be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the gas pipes, shall not be done when the engine(s) is running on gas.

15.11.5 Compressors, pumps and fuel gas 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 gas compressor or fuel handling 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 main tank valve	Automatic shutdown of gas supply to machinery space containing	Comments

			gas-fuelled engines	
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	X		
Bilge well high level 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 [and in ducting surrounding gas pipes] at 20% LEL	X			Note: ensure correct requirements for fuel lines vs. other gas pipes
Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines [and in ducting surrounding gas pipes] at 40% LEL	X	X[2)]		Note: ensure correct requirements for fuel lines vs. other gas pipes
Gas detection in compressor room and or fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in compressor room and or 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
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 machinery space containing gas-fuelled engines at 20% LEL	X			Gas detection only required for ESD protected machinery space
Gas detection on two detectors[1)] in machinery	X		X	Gas detection only required for ESD

space containing gas-fuelled engines at 40% LEL				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			
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)]	
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 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.

A-2
SPECIFIC REQUIREMENTS FOR SHIPS USING ETHYL OR METHYL ALCOHOL AS FUEL

1 In addition to Part A, the following paragraphs of Part A-1 apply to ships using ethyl or methyl alcohol as fuel:

Subject	Paragraphs	Comments
Material and general pipe design	5.1, 5.2…….	
Power generation	6.1, 6.2…..	
Fuel storage	7.1, 7.2…..	
Fuel supply to consumers	8.1, 8.2	
Bunkering	9.1, 9.2	
Ship design and arrangements	10.1, 10.2…	See additional requirements 2.1 below
Fire safety	11.1, 11.2…..	
Explosion protection	12.1, 12.2…….	
Ventilation	13.1, 13.2….	
Electrical installation	14.1, 14.2….	
Control, monitoring and safety systems	15.1, 15.2….	

2 ADDITIONAL REQUIREMENTS FOR SHIPS USING ETHYL OR METHYL ALCOHOL AS FUEL:

2.1 Containment for low-flashpoint liquids

Definitions (comments move to 2.2)

Independent tank means a fuel-containment envelope, which is not contiguous with, or part of, the hull structure. An independent tank is built and installed so as to eliminate whenever possible (or in any event to minimize) its stressing as a result of stressing or motion of the adjacent hull structure. An independent tank is not essential to the structural completeness of the ship's hull.

Integral tank means a fuel-containment envelope which forms part of the ship's hull and which may be stressed in the same manner and by the same loads which stress the contiguous hull structure and which is normally essential to the structural completeness of the ship's hull.

Gravity tank means a tank having a design pressure not greater than 0.07 MPa gauge at the top of the tank. A gravity tank may be independent or integral. A gravity tank shall be constructed and tested according to recognized standards, taking account of the temperature of carriage and relative density of the cargo.

2.1.1 Requirements

2.1.1.1 Tanks for low-flashpoint liquids shall be surrounded by cofferdams acting as secondary barriers.

2.1.1.2 Piping systems in tanks and their cofferdams shall have no connections with piping systems in the rest of the ship, apart from fuel pipes which shall be arranged as specified in other parts of this Code.

2.1.1.3 The cofferdam shall be arranged in one of the following ways:

- With gas detection and possibility for water filling upon detection of leakage. The water filling shall be through a system without permanent connections to water systems in safe areas. Emptying shall be done with a separate system. Bilge ejectors serving hazardous spaces shall not be permanently connected to the drive water system.

- Permanently water filled with arrangements as above

2.1.1.4 Access to tanks and cofferdams shall be direct from open deck and such as to ensure their complete inspection.

2.1.1.5 For access through horizontal openings, hatches or manholes, the dimensions shall be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be no less than 600 by 600 mm.

2.1.1.6 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening shall be not less than 600 mm by 800 mm at the height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

2.1.1.7 Smaller dimensions may be approved by the Administration in special circumstances, if the ability to traverse such openings or to remove an injured person can be provided to the satisfaction of the Administration.

2.2 Entrance to pump room

2.2.1 Entrance to fuel pump rooms shall be from open deck. [Air lock access] [Access from an enclosed space or from the open deck through an air lock] may be accepted upon special considerations. As a minimum, continuous gas detection and ventilation of the space will be required.

2.2.3 Pressure relief systems for low-flashpoint liquid fuel tanks

2.2.3.1 Tanks for low-flashpoint liquids shall be fitted with a breathing system for relief of pressure and vacuum. Such breathing shall be through pressure/ vacuum relief valves.

(Note: Controlled venting system as per IBC Code should be required for low-flashpoint fuel tank storage. The appropriate requirements of IBC Ch 8 should be included in this paragraph 7.7.2.)

From part A-1, 6.5.2 For liquids low-flashpoint [liquid] fuels or gases heavier than air the drainage of spills into a separate collection system shall be ensured. The collection system shall be equipped with gas detection and if necessary liquid level sensors.

PART B

[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 specific requirements given in this Code.

16.2 Testing

16.2.1 Testing during construction

16.2.1.1 All liquefied gas fuel tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 7.4.10.1 to 7.4.15.4, as applicable for the tank type.

16.2.1.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 7.4.14.3.1.

16.2.1.3 The gas tightness of the fuel containment system with reference to 7.3.3 shall be tested.

16.2.1.4 Requirements with respect to inspection of secondary barriers shall be decided by the Recognized Organization in each case, taking into account the accessibility of the barrier. See also 7.4.4.2

16.2.1.5 The Administration may require that for ships fitted with novel Type B independent tanks, or tanks designed according to 7.4.16.1 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 7.4.14.3.1. Similar instrumentation may be required for Type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

16.2.1.6 The overall performance of the liquefied gas fuel containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the liquefied gas fuel, in accordance with the survey procedure and requirements in 2.4 and the requirements of the Recognized Organization. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained and be available to the Administration.

16.2.1.7 The liquefied gas fuel containment system shall be inspected for cold spots during or immediately following the first loaded voyage. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with the requirements of the Recognized Organization.

16.2.2 Type A tanks

16.2.2.1 All Type A independent tanks shall be subjected to a hydrostatic or hydropneumatic test. 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 should 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.

16.2.3 Type B tanks

16.2.3.1 Type B independent tanks shall be subjected to a hydrostatic or hydropneumatic test as follows:

- The test shall be performed as required in 17.2.2.1 for Type A independent tanks
- 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 prototype test shall be monitored by the use of strain gauges or other suitable equipment.

16.2.4 Type C tanks

16.2.4.1 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_o. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

16.2.4.2 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.

16.2.4.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

16.2.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 16.2.4.1. to 16.2.4.3.

16.2.4.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of 7.4.15.3.6.1 shall be fully complied with.

16.2.4.6 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 16.2.4.1.

16.2.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks shall only 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.

16.2.5 Membrane tanks

16.2.5.1 Design development testing

16.2.5.1.1 The design development testing required in 7.4.15.4.1.2 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. 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 7.4.4.2 is to be based on the results of testing carried out on the prototype scaled model.

16.2.5.1.2 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.

16.2.5.2 Testing

17.2.5.3 In ships fitted with membrane liquefied gas fuel containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested. All hold structures supporting the membrane shall be tested for tightness before installation of the liquefied gas fuel containment system. Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

16.3 Gas piping systems

16.3.1 The requirements for testing shall 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.

16.3.2 Welding procedure tests shall be required for gas piping and 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 shall be in accordance with 17.6 below.

16.3.2*bis* Approval requirements for piping components, such as Type Approval or type testing needs to be included. Prototype testing for bellows and cryogenic valves needs to be suitably covered.
(Note: Needs to be reworded. It is proposed to include references to the standard referred in SIGTTO's publication on Cryogenic Valves. I will need those references)

16.4 Welding, post-weld heat treatment and non-destructive testing
(Note: Need look at the references.)

16.4.1 General

Welding shall be carried out in accordance with 6.5.

16.4.2 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 Recognized Organization may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

16.4.3 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 requirements of this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with; design temperatures colder than –10°C, or with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm.

.2 When such butt welded joints of piping sections are made by automatic welding procedures approved by the Recognized Organization, 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 For other butt-welded joints of pipes not covered by 5.9.3.1 and 5.9.3.2, 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.

16.5 Testing Requirements

16.5.1 Type testing of piping components

16.5.1.1 *Valves*

Each type of piping component 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. 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 rated 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* *acceptable to the Administration.

.5 Type testing of emergency shutdown valves used in liquid cargo piping systems shall include demonstration of closing characteristics in accordance with 18.10.2.1.3.

16.5.1.2 *Expansion bellows*

The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Recognized Organization, on those installed within the cargo tanks:

.1 Elements of the bellows, not pre-compressed, 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) 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.

16.5.1.3 The Administration may waive performance of the tests specified in 16.5.1.2 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 shall include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

16.5.2 System testing requirements

16.5.2.1 The requirements of this section apply to piping inside and outside the fuel tanks.

16.5.2.2 After assembly, all fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure is to at least 1.5 times the design pressure (1.25 times the design pressure where the test fluid is compressible) for liquid lines and 1.5 times the maximum system working pressure (1.25 times the maximum system working pressure where the test fluid is compressible) 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.

16.5.2.3 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.

16.5.2.4 In double wall fuel gas piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

16.5.2.5 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 Recognized Organization.]

16.6 Other test requirements

(Note:Having included test requirements from the IGC-Code, do we need 17.6 and if so all of it?)

16.6.1 Tensile tests: Generally, tensile strength shall 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 shall 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 shall be reported for information.

16.6.2 Bend tests: No fracture shall 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.

16.6.3 Charpy V-notch impact tests: Charpy tests shall be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (E), shall be no less than 27 J. The weld metal requirements for sub-size specimens and sinlge energy values shall be in accordance with the IGC Code paragraph 6.1.4. The results of fusion line and heat affected zone impact tests shall 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) shall 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 shall be in accordance with recognized standards. Impact testing is not required for piping with thickness less than 6 mm.]

PART C

[17 Training and operational requirements

17.1 Goal of part

17.2 Functional requirements

17.3 Training requirement

17.3.1 The whole operational crew of a cargo- or a passenger ship using fuel addressed by this code shall have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board. Additionally, crew members with a direct responsibility for the operation of fuel-related equipment on board shall receive special training. The company shall document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

Or

17.3.1 Personnel shall be adequately trained in the operational and safety aspects of handling fuels covered by this Code as required by the STCW Convention, the ISM Code and the Medical First Aid Guide (MFAG). As a minimum:
(Note: Currently no related training requirements in STCW Convention)

.1 All personnel shall be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions.

.2 Officers shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the fuel and a sufficient number of them shall be instructed and trained in essential first aid for the fuel carried.]

17.3.2 Gas-related emergency exercises shall be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents shall be reviewed and tested.

17.3.3 A training manual shall be developed and a training programme and exercises shall be specially designed for each individual vessel and its gas installations.[32]

[17.4 General (Note: 17.4-17.6 to be deleted based on STW feedback)

(Note: STW has been requested to consider matters related to training. For the time being the text is kept awaiting the feedback from the STW Sub-Committee)

17.4.1 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.

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[32] Reference is made to Resolution A.1050(27) "Revised Recommendations for Entering Enclosed Spaces Aboard Ships".

17.5 Category A training

17.5.1 The goal of the category A training shall 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.

17.5.2 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 shall 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.

17.5.3 The training shall 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 shall form part of the training, and shall take place at an approved safety centre.

17.6 Categories B and C training

17.6.1 Deck and engineer officers shall have gas training beyond the general basic training. Category B and category C training shall be divided technically between deck and engineer officers, which shall be determined by the Company's training manager and the ship's Senior Management team.

17.6.2 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., shall participate in all or parts of the training for categories B and C. The Company and [the Master] [the ship's Senior Management team] are responsible for arranging such training based on an evaluation of the concerned crew member's job instructions/area of responsibility on board.

17.6.3 The instructors used for such supplementary training shall be the same as outlined for category A.

17.6.4 All gas-related systems on board shall be reviewed. The ship's maintenance manual, gas supply system manual and manual for electrical equipment in explosion hazardous spaces and zones shall be used as a basis for this part of the training.

17.6.5 This regulation shall be regularly reviewed by the Company and onboard Senior Management team as part of the SMS system. Risk analysis shall be emphasized, and any risk analysis and sub-analyses performed shall be available to course participants during training.

17.6.6 If the ship's own crew will be performing technical maintenance of gas equipment, the training for this type of work shall be documented.

17.6.7 The Master and the Chief engineer officer shall give the basic safety crew on board their final clearance prior to the entry into service of the ship. The clearance document shall only apply to gas-related training, and it shall 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 shall be clearly evident what is regarded as gas-related training and what is regarded as other training.

17.6.8 The training requirements related to the gas system shall be evaluated in the same manner as other training requirements on board at least once a year. The training plan shall be evaluated at regular intervals.]

[17.7 Maintenance (Note: To be further considered)

17.7.1 A special maintenance manual shall be prepared for the gas supply system on board.

17.7.2 The manual shall include maintenance procedures for all technical gas-related installations, and shall comply with the recommendations of the suppliers of the equipment. The intervals for and the extent of the replacement/approval of gas valves shall be established. The maintenance procedure shall specify who is qualified to carry out maintenance.

17.7.3 A special maintenance manual shall 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 shall be performed in accordance with a recognized standard.(footnote: Refer to IEC 60079 17:2007 Explosive atmospheres – Part 17: Electrical installations inspection and maintenance)

17.7.4 Any personnel that shall carry out inspections and maintenance of electrical installations in explosion hazardous spaces, shall be qualified [pursuant to IEC 60079-17, item 4.2.]"

18 [OPERATIONAL REQUIREMENTS (BUNKERING OPERATIONS AND/OR OTHER OPERATIONS]

18.1 Goal

18.1.1 The goal of this chapter is to ensure that operational procedures for the loading, storage, [operation], maintenance, and inspection of systems for gas or low flash point 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

18.2.1 This chapter relates to the functional requirements of 5.3.1.3, 7.3.13, 9.3, 9.4, 9.5, 9.6, 10.7, 15.9.14, 18.4, 18.5 and 18.6 of this Code. In particular the following apply:

18.2.1.1 A copy of this Code, or national regulations incorporating the provisions of this Code, shall be on board every ship covered by this Code

18.2.1.2 The operational procedures shall ensure fuel connection and disconnection of transfer system to minimize risk of liquid release, reduces the release of cargo vapour to the atmosphere to an absolute minimum and keeps thermal stresses within design limits.

18.2.1.3 Records of the sulfur content of gas fuels loaded shall be maintained on board as required by MARPOL Annex VI (2009), Regulation 19/4.

18.2.1.4 The ship shall be provided with a suitably detailed fuel transfer manual, approved by the Administration, such that trained personnel can safely operate the fuel loading,

discharge, storage and transfer systems. This manual shall be a controlled document under the ISM code. The contents of the manual shall include but is not limited to:

.1 Overall operation of the ship from dry-dock to dry-dock, including procedures for system cooldown and warm-up, bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing
.2 Bunker temperature and pressure control and alarm and safety systems
.3 System limitations, cool down rates and maximum [fuel storage] tank temperatures prior to ~~loading~~ bunkering, including minimum ~~cargo~~ fuel temperatures, maximum tank pressures, transfer rates, filling limits and sloshing limitations.
.4 Operation of inert gas systems
.5 Fire-fighting and emergency procedures: operation and maintenance of fire fighting systems and use of extinguishing agents
.6 Specific fuel properties and special equipment needed for the safe handling of the particular fuel
.7 Fixed and portable gas detection
.9 Emergency shutdown and emergency release systems, where fitted
.10 A fuel system schematic / [piping and instrumentation diagram] ~~P&ID~~ shall be reproduced and permanently mounted in the vessels' bunker control station and at the bunker station.

18.3 Requirements for bunkering operations

18.3.1 Responsibilities

18.3.1.1 The responsibility and accountability for the safe conduct of the bunkering operation are jointly shared between the Master of the receiving vessel and the Master of the bunkering vessel or representative of the bunker station. Before the bunkering operation commences, the Master of the receiving vessel or his representative and the representative of the supplier 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
3. Complete and sign the bunker safety check-list.

The Person in Charge (PIC) of bunkering operations shall have evidence of completion of training required by [Chapter 17.4.1.2 or 17.4.1.3 of the Code] […..of the STCW Convention].

18.3.2 Pre-bunkering Tests

Prior to conducting bunkering operations, pre-bunkering tests 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 and calibration of portable gas detection equipment
4. Where fitted, ESD systems tested and proved operational in both cold and warm condition; automatic ESD from SSL and remote manual ESD tested
5. Operation of remote controlled valves (Note: shore delivery facilities are outside the scope of the Code)

Documentation of successful testing shall be indicated by the mutually agreed and executed bunkering safety checklist signed by both PIC's.

(Note: It is commented that the proposed list of tests is too extensive as pre-bunkering tests for each bunkering and is more suited for an annual check. A pre-bunkering check list to confirm that relevant equipment is mobilized and working and that required procedures are followed should be sufficient.)

18.3.3 Ship-Bunkering Facility Communications

Communications shall be maintained between the vessel PIC and the delivering facility 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.

Communication devices used in bunkering shall comply with recognized standards for such devices acceptable to the Administration

PIC's shall have direct and immediate communication with all personnel involved in the bunkering operation, which shall be demonstrated and confirmed during pre-bunkering testing and documented in the bunkering safety check list.

Where a ship shore link (SSL)or equivalent link to a delivering facility is provided for automatic ESD communications, the link shall conform to the recognized standards of the Administration, shall be compatible with the receiving vessel and delivering facility ESD system and be tested and proved operational prior to the commencement of bunkering.

18.3.4 Electrical Bonding

(Note: It is propose to delete text SB in 18.3.4 as the text states technical requirement for an insulating flange instead of an operational requirement) (Electrical grounding of the ship and shore facility is an operational issue and should remain in this section. The technical requirement for the use of an insulating flange on the shore bunkering line is outside the scope of the Code and can be deleted. This technical requirement will be covered by the recognized standard API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals and ICS Tanker Safety Guide Liquefied Gas)

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.

18.3.5 Conditions for Transfer

Warning signs shall be posted at the access points to the bunkering area listing fire safety precautions during fuel transfer.

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.

[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 vessel and shall be properly secured prior to connection to the fuel system.]

18.4 Requirements for enclosed space entry

18.4.1 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 vapors 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[33].

18.4.2 If it is necessary to gas-free and aerate a fuel storage hold space surrounding a Type A gas fuel tank for routine inspection and the tank contains liquefied gas fuel, the inspection shall be conducted when the tank contains the minimum amount of fuel to keep the tank cold. The fuel storage hold space shall be re-inerted as soon as the inspection is completed.

18.4.3 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.

18.5 Requirements for Inerting and purging of fuel systems

18.5.1 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.

18.5.2 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.

(Note: Section 9.1 of the IGC Code requires a piping system for cargo tanks to be gas-freed. It also permits the inert gas to be provided by a shore facility as earlier proposed. There is no equivalent requirement in the IGF Code; however, this process is needed for periodic survey. As an alternative, IGC Chapter 9 should be incorporated in Chapter 6: Fuel Containment Systems of the draft IGF Code.)

18.6 Hot work on or near fuel systems

18.6.1 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 made and proven safe for hot work and all approvals have been obtained.

[33] Refer to Resolution A.1050(27) “Revised Recommendations for Entering Enclosed Spaces Aboard Ships

PART X

ADDITIONAL GUIDANCE ON DOCUMENTATION

(Note: It is proposed to have requirements for documentation for all types of machinery. Either under each section or as a separate section I do not think time permits this but we should decide on having the documentation requirements for fuel cells under a separate fuel cell section)

x.1 Documentation for fuel cell installations

x.1.1 For ships where fuel cells are part of the power production for propulsion or other important consumers an overall description of the propulsion and power installation and operating philosophy for all relevant operating modes shall be submitted for information.

x.1.2 A failure mode and effect analysis shall be conducted for the ship, taking all safety aspects in relation to the fuel cell installation into account.[34] This document shall be submitted for approval.

x.1.3 Plans and particulars for the fuel cell shall be submitted for approval. This is typically to include:

- fuel cell principles
- functional description
- arrangement drawings of the fuel cell including dimensions, materials, operating temperatures, pressures, weights
- strength calculations of pressure containing components, or test reports
- documentation of compliance with environmental conditions, including calculations or test reports
- voltage and current levels in different parts of the cell
- maintenance plan (replacement of stack etc.)
- earthing principles
- safety devices with set points
- documentation of life time and availability, e.g. deterioration rate curve or similar.
- A failure mode and effect analysis (FMEA) examining all possible faults affecting the processes in the fuel cells shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.
- The power deterioration rate for the fuel cell shall be documented through analysis or test results, and shall consider different power levels and different modes of operation.
- Test programme[35]

x.1.4 For ships where the fuel cell power is used for essential, important or emergency services the reliability and availability shall be documented through analysis, complemented with results from development testing, as well as full scale testing.

x.1.5 For ships where the fuel cell power is not used for essential, important or emergency users a failure mode and effect analysis for the control, monitoring and safety systems for the whole installation including the support and supply systems shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.

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[34] The safety aspects in this connection are for instance explosion hazards, fire effects from the fuel cell itself or from the fuel cell support systems. If a fuel cell is connected to the grid any potential hazards affecting the ship's total power system should be included.

[35] The test programme can be based on the IEC standard 62282-3-1 "Stationary fuel cell power systems-Safety", but will also have to take the environmental and operating conditions in a ship into account.