RULES

PUBLICATION 72/P

SAFETY REQUIREMENTS FOR SHIPS USING LOW-FLASHPOINT GASES AS FUEL

January
2024

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

Publication 72/P – Safety Requirements for Ships Using Low-flashpoint Gases as Fuel – January 2024, is an extension of the requirements contained in *Part I, Rules for the Classification and Construction of Sea-Going Ships,* as well as in all other PRS *Rules*, in which reference to the *Publication* has been made*.*

The *Publication* was approved by the PRS Board on 21 December 2023 and enters into force on 1 January 2024.

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1 INTRODUCTION

1.1 This *Publication* contains technical requirements for ships using low-flashpoint gas (LNG, CNG, LPG, hydrogen) as fuel. Gas carriers using their cargo as fuel shall comply with the *Rules for the Classification and Construction of Sea-going Gas Tankers*. Ships provided with fuel cells using low-flashpoint gas as fuel shall comply with *Publication 37/I – Guidelines for the safety of ships using fuel cell power installations.*

1.2 The main objective of this *Publication* is to specify the requirements for the arrangement, installation, control and monitoring of engines, equipment and systems using low-flashpoint gas as fuel, in order to minimize the risks to the ship, its crew and the environment, taking into account the properties of the gaseous fuels used.

1.3 This *Publication* has been prepared based on the technical requirements of the following source documents: *IGF Code*, as amended, MSC.1/Circ.1666, *Interim Guidelines for the Safety of Ships Using LPG Fuels* and CCC 9/WP.3 *Draft Interim Guidelines for the Safety of Ships Using Hydrogen as Fuel*.

1.4 The editorial layout of the *Publication* generally corresponds to the layout of the *IGF Code.* Requirements of the *Code* which in principle apply to the use of LNG and CNG as fuel are marked with blue font and their original numbers (i.e. those from the *Code*) are given in brackets at the end of each paragraph.

1.5 The Publication takes also into account the requirements of IACS and IMO resolutions related to the *IGF Code*, which are marked either with purple font (common IACS and IMO resolutions) or blue font (IMO resolutions).

1.6 Specific requirements for the use of LPG as fuel are marked in red font throughout the *Publication*. Specific requirements for the use of hydrogen are given separately in Chapter 17 with references to particular chapters and paragraphs of this *Publication* (the *IGF Code*).

1.7 Where in the text of the *Publication* any technical arrangements are left to the decision/discretion of the Flag State Administration, then PRS, acting as a recognized organization (RO) on behalf of the Flag State Administration, will take appropriate decisions in accordance with the provisions of the Agreement with the Administration. If the Flag State Administration of the new construction is unknown (not yet decided), then PRS will make appropriate decisions on its own.

2 GENERAL

2.1 Application

2.1.1 This *Publication* is intended for ships to which SOLAS Convention, Part G, Chapter II-1, *Ships using low-flashpoint fuels*, applies.

2.1.2 A ship using conventional marine fuel and natural gas or petroleum gas as fuel (dual fuel ship) complying with the applicable requirements of Chapters 2 to 16 of this *Publication* is assigned one of the following additional marks in the symbol of class:

IGF DF LNG

IGF DF CNG

IGF DF LPG

2.1.3 A ship using conventional marine fuel and hydrogen as fuel (dual fuel ship) complying with the applicable requirements of Chapter 2 and Chapter 17 of this *Publication* is assigned the following additional mark in the symbol of class:

IGF DF H_2

2.1.4 A ship using conventional marine fuel and partly ready to use low-flashpoint gas as fuel in the future i.e. not fully equipped and not in full compliance with the requirements of Chapters 2 to 16 or Chapter 2 and Chapter 17 of this *Publication* is assigned of one of the following additional marks in the symbol of class:

LNG READY

CNG READY

LPG READY

H_2 READY

The scope of ship's readiness as regards the hull structure, fuel tank(s) and associated systems, fuel bunkering, gas consumers (internal combustion engines, turbines, boilers) and fuel supply systems to gas consumers is specified in the *Certificate of Class* under paragraph *Other characteristics*.

2.1.5 Ships other than those subject to SOLAS Convention may be exempted from particular requirements of the *Publication*, subject to thorough consideration and acceptance of the deviations by PRS.

2.2 Definition

For the purposes of this *Publication*, the definitions contained in the SOLAS Convention, Chapter II-2 and those given below, apply.

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. (IGF Code, 2.2.1)

2.2.2 ***Auto-ignition temperature*** means the lowest temperature at which the fuel spontaneously ignites in normal atmosphere without an external source of ignition, such as a flame or spark. (MSC.1/Circ.1666, 2.2.3)

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

2.2.4 ***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. (IGF Code, 2.2.3)

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*. (IGF Code, 2.2.4)

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

2.2.6 ***CNG*** means compressed natural gas (see also 2.2.26). (IGF Code, 2.2.5)

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

2.2.8 ***Degree of dilution*** means a measure of the ability of ventilation or atmospheric conditions to dilute a release to a safe level. The degree of dilution is defined as high, medium and low (refer to IEC 60079-10-1, 6.5.4). (MSC.1/Circ.1666, 2.2.7)

2.2.9 ***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. (IGF Code, 2.2.7)

2.2.10 ***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. (IGF Code, 2.2.8)

2.2.11 ***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. (2.2.9)

2.2.12 ***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. (IGF Code, 2.2.10)

2.2.13 ***Effectiveness of ventilation*** refers to the effect of ventilation to control the diffusion and persistence of an explosive gas atmosphere due to gas leakage, depending on the degree and efficiency of ventilation (refer to IEC 60079-10-1). (MSC.1/Circ.1666, 2.2.6)

2.2.14 ***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*. (IGF Code, 2.2.11)

* See also definition in IEC 60092-502:1999.

2.2.15 ***ESD*** means emergency shutdown. (IGF Code, 2.2.12)

2.2.16 ***Explosion*** means a deflagration event of uncontrolled combustion. (IGF Code, 2.2.13)

2.2.17 ***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. (IGF Code, 2.2.14)

2.2.18 ***Filling limit (FL)*** means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature. (IGF Code, 2.2.16)

2.2.19 ***Fuel*** in this *Publication* means any type of gaseous fuel (LNG, CNG, LPG and hydrogen), unless otherwise specified.

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

The spaces around the fuel tank are defined as follows:

- **.1** ***Fuel storage hold space*** is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;
- **.2** ***Interbarrier space*** is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and
- **.3** ***Tank connection space*** is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces. (IGF Code, 2.2.15)

IACS and IMO interpretation:

1. *A tank connection space may be required also for tanks on open deck. This may apply for ships where restriction of hazardous areas is safety critical. A tank connection space may also be necessary in order to provide environmental protection for essential safety equipment related to the gas fuel system like tank valves, safety valves and instrumentation.*
2. *A tank connection space may also contain equipment such as vaporizers or heat exchangers. Such equipment is considered to only contain potential sources of release, but not sources of ignition. (IACS UI GF3, MSC.1/Circ.1558)*

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

IACS and IMO interpretation:

A tank connection space which has equipment such as vaporizers or heat exchangers installed inside is not regarded as a fuel preparation room. Such equipment is considered to only contain potential sources of release, but not sources of ignition. (IACS UI GF4, MSC.1/Circ.1558)

2.2.22 ***Gas*** means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C. (IGF Code, 2.2.18)

2.2.23 ***Gas consumer*** means any unit within the ship using gas as a fuel. (IGF Code, 2.2.19)

2.2.24 ***Gas dispersion analysis*** means the analysis of the dispersion behaviour of gases using appropriate modelling techniques such as computational fluid dynamics (CFD) analysis. (MSC.1/Circ.1666, 2.2.4)

2.2.25 ***Gas only engine*** means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel. (IGF Code, 2.2.20)

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

2.2.27 ***High pressure*** means a maximum working pressure greater than 1.0 MPa. (IGF Code, 2.2.22)

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

Independent tanks are divided into the following types:

- **.1** ***Type A independent tank*** – a tank designed using classical ship-structural analysis procedures, without taking into account the criteria preventing the propagation of surface cracks, for which a complete secondary barrier is required;
- **.2** ***Type B independent tank*** – a tank designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics, for which a partial secondary barrier is required
- **.3** ***Type C independent tank*** – a tank designed based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria, for which a secondary barrier is not required.

2.2.29 ***LEL*** means the lower explosive limit. (IGF Code, 2.2.24)

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

2.2.31 ***LNG*** means liquefied natural gas. (IGF Code, 2.2.26)

2.2.32 ***LPG*** means liquefied petroleum gas. It is mainly composed of a mixture of propane (C_3H_8) and butane (C_4H_{10}) and may contain small amounts of other hydrocarbons and impurities. In these *Interim Guidelines*, petroleum gas either in its liquefied or gaseous state is referred to as LPG. When it is necessary to distinguish between the liquefied state and the gas state, LPG in the liquefied state is referred to as LPG liquid, and LPG in the gaseous state is referred to as LPG gas. (MSC.1/Circ.1666, 2.2.1)

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

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

2.2.35 ***MARVS*** means the maximum allowable relief valve setting. (IGF Code, 2.2.29)

2.2.36 ***MAWP*** means the maximum allowable working pressure of a system component or tank. (IGF Code, 2.2.30)

2.2.37 ***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. (IGF Code, 2.2.31)

2.2.38 ***Multi-fuel engines*** means engines that can use two or more different fuels that are separate from each other. (IGF Code, 2.2.32)

2.2.39 ***Non-hazardous area*** means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment. (IGF Code, 2.2.33)

2.2.40 ***Open deck*** means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead. (IGF Code, 2.2.34)

2.2.41 ***Risk*** is an expression for the combination of the likelihood and the severity of the consequences. (IGF Code, 2.2.35)

2.2.42 ***Reference temperature*** means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs). (IGF Code, 2.2.36)

2.2.43 ***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. (IGF Code, 2.2.37)

2.2.44 ***Semi-enclosed space*** means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur*. (IGF Code, 2.2.38)

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

2.2.45 ***Source of release*** means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed. (IGF Code, 2.2.39)

2.2.46 ***Unacceptable loss of power*** means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3. (IGF Code, 2.2.40)

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

2.2.48 ***Ventilation analysis*** means the analysis of the ventilation efficiency of a space using appropriate modelling techniques such as CFD analysis. (MSC.1/Circ.1666, 2.2.5)

2.2.49 ***Pressure relief valve (PRV)*** means a valve preventing the increase of pressure in the gas fuel tank above the permissible pressure value of the design vapor pressure P_0.

2.2.50 ***Sources of ignition*** may include:

.1 electrical ignition sources such as static electricity, arcing discharges;
.2 mechanical sources of ignition, such as shock or friction, which may cause sparks or hot spots;
.3 hot surfaces of engines and devices with a temperature above 500°C;
.4 sources of ignition from cargo carried, such as cars and trucks on car ferries,
.5 sources of ignition resulting from carelessness of passengers.

2.3 Design documentation

Prior to the commencement of construction/reconstruction of a gas-fuelled ship, the following technical documentation shall be submitted to PRS Head Office for appraisal, as applicable:

.1 General arrangement plan, with complete information about the ship design and intended operational profile, including a description of the vessel arrangements, essential services and the planned operating capability and functionality of the main propulsion and auxiliary systems, that are going to use gas as fuel.
.2 Reports with results of risk studies conducted according to a recognised standard. The content of risk studies should document the risk identification and ways how they are going to be eliminated or mitigated with clearly identified and an appropriate level of safety, dependability and hazardous areas classification.
.3 Hazardous area classification plan, including the division into hazardous areas.
.4 Schedule of electrical and mechanical equipment located in hazardous areas.
.5 Plans of gas fuel storage tanks and pressure vessels, including filling and relief arrangements with details of construction.
.6 Drawing of gas tanks including hatches, pipes and any openings to the tank.
.7 Drawing of gas tanks supports and stays, including anti-flotation arrangement.
.8 Calculation of design loads for gas tanks and supports.
.9 Complete strength analysis of fuel tanks including interaction between tanks and hull.
.10 Thermal stress analysis for intended liquefied gas storage system.
.11 Secondary barrier drawing of gas fuel tanks.
.12 Drawing of structural reinforcements of hull structure.
.13 Penetrations of gas fuel pipelines through gas-tight bulkheads.
.14 Plan of non-destructive testing (NDT) of gas fuel system tanks/pipelines.
.15 Non-destructive testing (NDT) procedures.
.16 Procedures for strength and tightness testing of fuel gas tanks/fuel gas system.
.17 Procedure of dished ends forming of the construction of gas fuel tanks.
.18 Specification of stress reliving procedures for type C independent tanks.
.19 Insulation plan of gas fuel tanks.
.20 Construction tolerances.
.21 Gas fuel system plan, with associated piping details and necessary calculations including maximum potential generation of gas and the associated systems to handle it under all envisaged operating conditions.
.22 Plan of gas bunkering stations with details of safety measures.
.23 Arrangement of gas fuel storage tanks, plans of gas process equipment and gas machinery (e.g. heat exchangers, compressors, etc.), with details of their location relative to accommodation spaces, high fire risk areas, service and control spaces, water ballast, fuel oil, and other tanks containing flammable substances.
.24 Diagrams Piping and Instrumentation Diagrams (P & IDs) and Process Flow Diagrams (PFDs) with details documenting gas-containing equipment. Diagrams should cover all piping and equipment from the bunkering station connection to the engines.
.25 Plan of boil-off handling system.
.26 Plan of gas fuel piping system with details of piping design including fixing and insulation, double wall ducting or piping (dual ducting), valves and fittings, pressure relief, expansion, and ventilation and purging arrangements.
.27 Fatigue analysis for all pressurised gas piping arrangements subjected to vibration or pulsating pressure where failure of the pipe or its connection or a component would be the cause of a main propulsion being unavailable. The analysis is to recognise the pressures and fluctuating stresses that the piping system may be subject to in normal service.
.28 Piping stress analysis: a complete stress analysis for each branch of the piping system (including storage tanks, equipment and piping systems) is to be undertaken for high

pressure gas piping systems, or piping systems with a design temperature of −110°C or lower. The analysis is to consider all stresses due to weight of pipes, including acceleration loads (if significant), internal pressure, thermal expansion and contraction, and loads induced by hog and sag of the ship. The stress analysis is to be undertaken according to a recognized standard.

.29 Plans of ventilation system for the machinery spaces, machinery enclosures or casings including air-locks, ventilation hoods, pipe ducting and any dampers in them, closing appliances and the position of the controls for stopping the system. Plans are to indicate hazardous areas where appropriate.

.30 Plans of enclosures or casings for gas-fuelled machinery and any air locks where access is required.

.31 Description of emergency shutdown arrangements, including a list of control, monitoring and alarm points.

.32 Description and plans of gas fuel control and monitoring systems and fuel changeover arrangements for dual-fuelled engines, including line diagrams of control circuits and lists of monitoring, control and alarm points.

.33 Quality plans for sourcing, design, installation and testing of all components used in the gas fuel system installed with the gas receiver.

.34 Report of type testing of the IC engines with electronic controls or a proposed test plan at the manufacturer with the electronic controls operational, in order to verify suitability of the electronic control system and correct functioning during normal operation and identified failure modes.

.35 Testing programs for IC engines manufacturer and commissioning prior to sea trials, to demonstrate that the gas-fuelled engine is capable of operating as described in the design statement, including any testing required to confirm the conclusions of the Failure Mode and Effects Analysis (FMEA) or alternative recognised analysis technique for system reliability. The test programs are to identify all modes of operation and the sea trials are to include typical port manoeuvres under all intended engine or propulsion system operating modes.

.36 A cause and effect diagram to indicate the results of activation of each shutdown, shut-off and cut-out associated with the gas fuel system including engine operation and bunkering.

.37 Plans for testing and inspection of gas storage and supply systems at ship port and sea trials.

.38 Instructions and operating manuals with descriptions of the mounting details, together with operating and maintenance instructions. The documents are to contain procedures for modifications to control systems. Equipment manufacturers' instructions are to include the drawings and diagrams necessary for commissioning and putting into service, maintenance, inspection and of correct operation checks, advisory for repairs of the machinery and use of correct spares and service tools, and practical safety instructions.

.39 Gas fuel bunkering arrangement plans, and operation and maintenance instruction manuals.

.40 Safety philosophy for the prevention of crankcase explosions in DFD or gas only engines.

.41 Fixed gas detection and alarm system plans.

.42 Plan with the arrangement of fire main system protecting any space included in the fuel storage hold space, fuel containment system, gas storage tanks, and ventilation trunks to such spaces, if any. The plan should show the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross-connections to any other system.

.43 Plan with arrangement of fire-fighting systems (e.g. water-spray) protecting any space included in the fuel storage hold space, fuel containment system, gas storage tanks, and ventilation trunks to such spaces, if any. The plan is to provide details that include calculations for the quantities of the media used and the proposed rates of application.

.44 Plan of the dry powder system protecting the bunkering station. The plan should show details of system arrangements, including calculations for the quantities of the media used and the proposed rates of application.

.45 Structural fire protection plan showing the main fire zones, bulkheads and decks separating the main fire zones, including the categorization of the fire hazard of the spaces and the classes of all fire divisions; the plan should also allow identification of different types of space and their use.

.46 Plan showing the details of construction of the fire protection bulkheads and decks.

2.4 Certificates and documents of compliance

Devices and components of on-board installations using gaseous fuel should be delivered with appropriate certificates and/or documents of compliance. The presented certificates and documents of compliance are subject to verification and acceptance by the Administration or an authorized institution.

2.5 Operational documentation

Documentation on the safe operation and maintenance of gas fuel systems should be kept on board the ship, including:

.1 copy of *IGF Code,* or national regulations incorporating the provisions of this Code;

.2 maintenance procedures and information for all gas related installations;

.3 operational procedures, including a suitable detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems; and

.4 suitable emergency procedures. (IGF Code, 18.2)

.5 for LPG and H_2 additionally relevant up-to-date IMO Guidelines for the safety of ships using such fuels (see 1.3).

2.6 Maintenance and repair procedures

2.6.1 Maintenance and repair procedures shall include considerations with respect to the gas fuel tank location and adjacent spaces (see Chapter 5). (IGF Code, 18.3.1)

2.6.2 In-service survey, maintenance and testing of the fuel containment system are to be carried out in accordance with the inspection/survey plan required by 6.4.1.8, which states as below:

"6.4.1.8 An inspection/survey plan* for the liquefied gas fuel containment system shall be developed and approved by the Administration. The inspection/survey plan shall identify aspects to be examined and/or validated during surveys throughout the liquefied gas fuel containment system's life and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting liquefied gas fuel containment system design parameters. The inspection/survey plan may include specific critical locations as per 6.4.12.2.8 or 6.4.12.2.9". (IGF Code, 18.3.2)

* ***IACS Recommendation:***

1. *In developing the inspection/survey plan, the requirements for the survey of liquefied gas fuel containment systems are to be in accordance with the requirements of IACS UR Z16, Section 2.2 except as noted below:*
   1.1. *The tank insulation and tank support arrangements should be visually examined. Non-destructive testing may be required if conditions raise doubt to the structural integrity.*
   1.2. *Vacuum insulated independent fuel storage tanks of type C without access openings need not be examined internally. Where fitted, the vacuum monitoring system should be examined and records should be reviewed.*
2. *For vessels which need not comply with the IGF Code, as amended, even though an inspection/survey plan is not required, the survey for liquefied gas fuel containment systems should be in accordance with paragraph 1. (IACS REC. 148)*

2.6.3 The procedures and information shall include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces shall be performed in accordance with a recognized standard*. (IGF Code, 18.3.3)

* Refer to IEC 60079 17:2007 *Explosive atmospheres – Part 17: Electrical installations inspection and maintenance.*

2.7 Fuel handling manual

2.7.1 The fuel handling manual, required by 2.5.3, shall include but is not limited to:

.1 overall operation of the ship from dry-dock to dry-dock, including procedures for system cool down and warm up, bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing;
.2 bunker temperature and pressure control, alarm and safety systems;
.3 system limitations, cool down rates and maximum fuel storage tank temperatures prior to bunkering, including minimum fuel temperatures, maximum tank pressures, transfer rates, filling limits and sloshing limitations;
.4 operation of inert gas systems;
.5 firefighting and emergency procedures: operation and maintenance of firefighting systems and use of extinguishing agents;
.6 specific fuel properties and special equipment needed for the safe handling of the particular fuel;
.7 fixed and portable gas detection operation and maintenance of equipment;
.8 emergency shutdown and emergency release systems, where fitted; and
.9 a description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover. (IGF Code, 18.4.2.1)

2.7.2 A fuel system schematic/piping and instrumentation diagram (P&ID) shall be reproduced and permanently mounted in the ship's bunker control station and at the bunker station. (IGF Code, 18.4.2.2)

2.8 Alternative designs

2.8.1 This *Publication* (Code) contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint gaseous fuels. (IGF Code, 2.3.1)

2.8.2 Alternative designs of appliances and arrangements related to the usage of low-flashpoint gaseous fuels may differ from those specified in this *Publication,* provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters. (IGF Code, 2.3.2)

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

2.9 Onboard tests

2.9.1 Tests of gas-supply appliances are to be carried out in accordance with the test program agreed with the Administration. In general, the testing requirements should be at least equivalent to those for oil fuelled equipment.

2.9.2 During sea trials, operation tests of the main propulsion engines shall be carried out when fuelled with gaseous fuel, and for dual-fuel engines – operation tests of the engine and its control systems during the transition from oil fuel to gaseous fuel operation shall be carried out.

2.9.3 All indicators, alarms and safety system functions related to the gas fuel supply system are to be tested in accordance with the test program agreed with the Administration. When loading gaseous fuel for the first time, check the high and high level alarms by raising the liquid level in the fuel tank to the alarm point.

3 GOAL AND FUNCTIONAL REQUIREMENTS (IGF Code, 3)

3.1 Goal

The goal of this *Publication* (Code) is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas or low-flashpoint fuel as fuel. (IGF Code, 3.1)

3.2 Functional requirements (IGF Code, 3.2)

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. (IGF Code, 3.2.1)

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. (IGF Code, 3.2.2)

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

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

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

3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented. (IGF Code, 3.2.6)

3.2.7 System components shall be protected against external damages. (IGF Code, 3.2.7)

3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions. (IGF Code, 3.2.8)

3.2.9 It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods. (IGF Code, 3.2.9)

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. (IGF Code, 3.2.10)

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

3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable. (IGF Code, 3.2.12)

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

3.2.14 Fixed gas detection suitable for all spaces and areas concerned shall be arranged. (IGF Code, 3.2.14)

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

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. (IGF Code, 3.2.16)

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. (IGF Code, 3.2.17)

3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation. (IGF Code, 3.2.18)

4 GENERAL REQUIREMENTS (IGF Code, 4)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 4 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 4.2.1)

4.1 Goal

The goal of this paragraph 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. (IGF Code, 4.1)

4.2 Risk assessment (IGF Code, 4.2)

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

4.2.2 For ships using natural gas, the risk assessment required by 4.2.1 need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the Annex to this *Publication*. (IGF Code, 4.2.2)

For ships using petroleum gas, the risk assessment should also address paragraphs 5.10.1, 6.3.4, 10.5.2, 13.4.2 and 15.2.2 of this *Publication*. (MSC.1/Circ.1666, 4.2.2)

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

* See Annex 2 – IACS REC. 146 *Risk assessment as required by the IGF Code*.

4.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release[1)] and potential ignition sources shall not:

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

.1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;
.2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;
.3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;
.4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;
.5 damage life-saving equipment or associated launching arrangements;
.6 disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;

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

.8 prevent persons access to life-saving appliances or impede escape routes. (IGF Code, 4.3)

5 SHIP DESIGN AND ARRANGEMENT (IGF Code, 5)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 5 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 5.3.1)

5.1 Goal

The goal of this paragraph is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refueling systems. (IGF Code, 5.1)

5.2 Functional requirements (IGF Code, 5.2)

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

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

.2 fuel containment systems, fuel piping and other fuel sources of release shall be so located and arranged that released gas is lead to a safe location in the open air;
For LPG, bearing in mind that the gas is heavier than air, locations of the release should be determined taking into consideration the surrounding arrangement so as to minimize the possibility of accumulation of the gas released on the open space and to facilitate dispersion into the atmosphere; (MSC.1/Circ.1666, 5.2.2)

.3 the access or other openings to spaces containing fuel sources of release shall be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;
For LPG, specific gravity and dispersion characteristics of the gas should be taken into account; (MSC.1/Circ.1666, 5.2.3)

.4 fuel piping shall be protected against mechanical damage;

.5 the propulsion and fuel supply system shall be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

.6 the probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery shall be minimized. (IGF Code, 5.2.1)

5.3 General requirements (IGF Code, 5.3)

5.3.1 Fuel storage tanks shall be protected against mechanical damage. (IGF Code, 5.3.1)

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

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

.1 The fuel tanks shall be located at a minimum distance of B/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught;

where:

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

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

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

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

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

   .1 for V_c below or equal 1,000 m^3, 0,8 m;
   .2 for 1.000 m^3 < V_c < 5.000 m^3, 0,75 + $V_c \times 0{,}2/4.000$ m;
   .3 for 5.000 m^3 < V_c < 30.000 m^3, 0,8 + $V_c/25.000$ m; and
   .4 for V_c > 30.000 m^3, 2 m,

   where:

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

.5 The lowermost boundary of the fuel tank(s) shall be located above the minimum distance of $B/15$ or 2,0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.

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

.7 The fuel tank(s) shall be abaft a transverse plane at 0,08L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for cargo ships,

where:

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

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3. (IGF Code, 5.3.3)

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

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

* The value f_{CN} accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

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

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

where:

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

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

$$f_t = 1 - r\,(\times 1, \times 2, b)\ *$$

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

f_v is calculated by use of the formulations for factor v contained in SOLAS regulation II-1/7-2.6.1.1 and reflects the probability that the damage is extending vertically above the lowermost boundary of the fuel tank. The formulations to be used are:

$$f_v = 1{,}0 - 0{,}8\ ((H - d)/7{,}0)),\ \text{if}\ (H - d)$$

is less than or equal to 7,8 m. f_v shall not be taken greater than 1.

$$f_v = 0{,}2 - 0{,}2\ ((H - d) - 7{,}8)/4{,}7),$$

in all other cases f_v shall not be taken less than 0,

where:

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

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

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

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

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

.1 For passenger ships: $B/10$ but in no case less than 0,8 m. However, this distance need not be greater than $B/15$ or 2 m whichever is less where the shell plating is located inboard of $B/5$ or 11,5 m, whichever is less, as required by 5.3.3.1.

.2 For cargo ships:

.1 for V_c below or equal 1.000 m^3, 0,8 m;

.2 for 1.000 m^3 < V_c < 5.000 m^3, 0,75+ $V_c \times 0{,}2/4.000$ m;

.3 for 5.000 m^3 < V_c < 30.000 m^3, 0,8 + $V_c/25.000$ m; and

.4 for V_c> 30.000 m^3, 2 m,

where:

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

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

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

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3. (IGF Code, 5.3.4)

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

.1 fuel storage hold spaces shall be segregated from the sea by a double bottom; and
.2 the ship shall also have a longitudinal bulkhead forming side tanks. (IGF Code, 5.3.5)

5.4 Machinery space concepts (IGF Code, 5.4)

5.4.1 In order to minimize the probability of a gas explosion in a machinery space with gas-fuelled machinery one of these two alternative concepts may be applied:

.1 *Gas safe machinery spaces:* Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

.2 *ESD-protected machinery spaces:* Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery shall be automatically executed while equipment or machinery in use or active during these conditions shall be of a certified safe type.

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

Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements. (IGF Code, 5.4.1)

IACS and IMO interpretation:

Premixed engines using fuel gas mixed with air before the turbocharger shall be located in ESD protected machinery spaces. (IACS UI GF5 and MSC.1/Circ.1558)

5.4.2 For LPG, a single failure of fuel systems should not lead to a gas release in the machinery space, i.e. only gas safe machinery space concept should be accepted. (MSC.1/Circ.1666, 5.3.2)

5.5 Requirements for gas safe machinery space (IGF Code, 5.5)

5.5.1 A single failure within the fuel system shall not lead to a gas release into the machinery space. (IGF Code, 5.5.1)

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

5.6 Requirements for ESD-protected machinery spaces (IGF Code, 5.6)

5.6.1 ESD protection shall be limited to machinery spaces that are certified for periodically unattended operation. (IGF Code, 5.6.1)

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: (IGF Code, 5.6.2)

- **.1** gas detector;
- **.2** shutoff valve;
- **.3** redundancy; and
- **.4** efficient ventilation. (IGF Code, 5.6.2)

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

- **.1** Engines for generating propulsion power and electric power shall be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces.
- **.2** The gas machinery space shall contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function.
- **.3** A fixed gas detection system arranged to automatically shutdown the gas supply, and disconnect all electrical equipment or installations not of a certified safe type, shall be fitted. (IGF Code, 5.6.3)

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

5.6.5 ESD protected machinery spaces separated by a single bulkhead shall have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space. (IGF Code, 5.6.5)

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

5.6.7 The ventilation system of ESD-protected machinery spaces shall be arranged in accordance with 13.5. (IGF Code, 5.6.7)

5.6.8 The requirements of this sub-chapter 5.6 do not apply to ships using LPG as fuel. ESD-protected machinery spaces may be permitted, provided that the requirements of alternative design (SOLAS II-1/55) are met, to the satisfaction of the Administration. (MSC.1/Circ.1666, 5.3.3)

5.7 Location and protection of fuel piping (IGF Code, 5.7)

5.7.1 Fuel pipes shall not be located less than 800 mm from the ship's side. (IGF Code, 5.7.1)

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

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

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. (IGF Code, 5.7.4)

5.7.5 Gas fuel piping in ESD protected machinery spaces shall be protected against mechanical damage. (IGF Code, 5.7.5)

5.7.6 For LPG, double barrier around fuel piping systems should be continuous and not have openings in machinery spaces (see 5.5). (MSC.1/Circ.1666, 5.3.4)

5.8 Fuel preparation room

Fuel preparation rooms shall be located on an open deck, unless those rooms are arranged and fitted in accordance with the regulations of this *Publication* (Code) for tank connection spaces. (IGF Code, 5.8)

IACS and IMO interpretation:

Interpretation regarding protection against cryogenic leakage and control of hazardous zones in fuel preparation rooms on open deck

1. *Fuel preparation rooms, regardless of location, shall be arranged to safely contain cryogenic leakages.*
2. *The material of the boundaries of the fuel preparation room shall have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection.*
3. *The fuel preparation room shall be arranged to prevent surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of cryogenic liquids.*
4. *The fuel preparation room 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. (IACS UI GF6 and MSC.1/Circ.1558)*

5.9 Bilge systems (IGF Code, 5.9)

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

5.9.2 Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The bilge system shall not lead to pumps in safe spaces. Means of detecting such leakage shall be provided. (IGF Code, 5.9.2)

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

5.9.4 For LPG, the bilge systems in the hazardous area should also be arranged separately for each space and discharged overboard or to an enclosed tank fitted with a gas detector. Where bilge piping of two or more hazardous areas is connected, means should be provided to prevent the gas in one area from entering into other areas through the connected bilge pipes. (MSC.1/Circ.1666, 5.3.5)

5.10 Drip trays (IGF Code, 5.10)

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. (IGF Code, 5.10.1)

For LPG, drip trays identified by the risk assessment in accordance with 4.2 should be equipped with means to detect leakage and shut off the fuel if required. (MSC.1/Circ.1666, 5.3.6)

5.10.2 Drip trays shall be made of suitable material. (IGF Code, 5.10.2)

5.10.3 The drip tray shall be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel. (IGF Code, 5.10.3)

This paragraph does not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 5.3.6)

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

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

5.11 Arrangement of entrances and other openings in enclosed spaces (IGF Code, 5.11)

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

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

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. (IGF Code, 5.11.3)

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

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

5.12 Airlocks (IGF Code, 5.12)

5.12.1 An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of the *International Convention on Load Lines*, the door sill shall not be less than 300 mm in height. The doors shall be self-closing without any holding back arrangements. (IGF Code, 5.12.1)

5.12.2 Airlocks shall be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space. (IGF Code, 5.12.2)

5.12.3 The airlock shall be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events shall be evaluated in the risk analysis according to 4.2. (IGF Code, 5.12.3)

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

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

5.12.6 For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space is to be restricted until the ventilation has been reinstated. Audible and visual alarms shall be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost. (IGF Code, 5.12.6)

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. (IGF Code, 5.12.7)

5.13 Location of LPG outlets

5.13.1 LPG gas line from the following should be led to a vent mast:

.1 the pressure relief valve of the LPG tank; and
.2 vent lines and bleed lines for gas fuel systems.

5.13.2 LPG liquid line from the following should be led to a fuel tank:

.1 the pressure relief valve of the liquid fuel supply pipe;
.2 vent line and bleed line of liquid fuel supply piping; and
.3 pressure relief valve in bunkering line.

Where it is not practicable, the line may be led to a vent mast but liquid release from the outlet of vent is not acceptable. (MSC.1/Circ.1666, 5.3.6)

6 FUEL CONTAINMENT SYSTEM (IGF Code, 6)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 6 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 6.3.1)

6.1 Goal

The goal of this Chapter is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fuelled ship. (IGF Code, 6.1)

6.2 Functional requirements

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

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

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

IACS and IMO interpretation:

Interpretation regarding protection against cryogenic leakage and control of hazardous zones in fuel preparation rooms on open deck

1. *Fuel preparation rooms, regardless of location, shall be arranged to safely contain cryogenic leakages.*
2. *The material of the boundaries of the fuel preparation room shall have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection.*
3. *The fuel preparation room shall be arranged to prevent surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of cryogenic liquids.*
4. *The fuel preparation room 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. (IACS UI GF6 and MSC.1/ Circ.1558)*

.2 flammable fuels spreading to locations with ignition sources;
.3 toxicity potential and risk of oxygen deficiency due to fuels and inert gases;
.4 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and
.5 reduction in availability of LSA.

.2 the pressure and temperature in the fuel tank shall be kept within the design limits of the containment system and possible carriage requirements of the fuel;
.3 the fuel containment arrangement shall be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and
.4 if portable tanks are used for fuel storage, the design of the fuel containment system shall be equivalent to permanent installed tanks as described in this Chapter. (IGF Code, 6.2)
.5 additionally for LPG, the fuel containment system should be designed considering various characteristics of all possible compositions of the LPG. (MSC.1/Circ.1666, 6.2.5)

6.3 General requirements (IGF Code, 6.3)

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

This paragraph does not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 6.3.2)

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

6.3.3 A fuel containment system located below deck shall be gas tight towards adjacent spaces. (IGF Code, 6.3.3)

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. (IGF Code, 6.3.4)

For LPG, if the fuel tank is located in enclosed space, a tank connection space should be provided separately from fuel storage hold space. For the fuel tank located on an open deck, a tank connection space should also be provided where escaped gas may accumulate on the open deck or enter in non-hazardous space such as accommodation space and machinery space based on the risk assessment (see 4.2). (MSC.1/Circ.1666, 6.3.3)

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. (IGF Code, 6.3.5)

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. (IGF Code, 6.3.6)

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. (IGF Code, 6.3.7)

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

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. (IGF Code, 6.3)

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. (IGF Code, 6.3)

IACS and IMO interpretation:

Whether a drip tray is needed or not is to be in accordance with the following:

1. *When the tank is located on the open deck, drip trays are to be provided to protect the deck from leakages from tank connections and other sources of leakage.*
2. *When the tank is located below the open deck but the tank connections are on the open deck, drip trays are to be provided to protect the deck from leakages from tank connections and other sources of leakage.*

3. *When the tank and the tank connections are located below the deck, all tank connections are to be located in a tank connection space. Drip trays in this case are not required.* *(IACS UI GF2 and MSC.1/Circ.1605)*

6.3.11 Means shall be provided whereby liquefied gas in the storage tanks can be safely emptied. (IGF Code, 6.311)

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

6.4 Liquefied gas fuel containment (IGF Code, 6.4)

6.4.1 General (IGF Code, 6.4.1)

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

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. (IGF Code, 6.4.1.2)

6.4.1.3 The design life of portable tanks shall not be less than 20 years. (IGF Code, 6.4.1.3)

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.* (IGF Code, 6.4.1.4)

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* See – IACS REC. 34 - *Standard Wave Data* (PRS' Publication 35/I *Wave loads on ships*)

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

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. (IGF Code, 6.4.1.5)

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

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

.1 internal pressure;
.2 external pressure;
.3 dynamic loads due to the motion of the ship in all loading conditions;
.4 thermal loads;
.5 sloshing loads;
.6 loads corresponding to ship deflections;
.7 tank and liquefied gas fuel weight with the corresponding reaction in way of supports;
.8 insulation weight;
.9 loads in way of towers and other attachments; and
.10 test loads.

.2 *Fatigue Design Conditions* – The liquefied gas fuel containment system structure and its structural components shall not fail under accumulated cyclic loading.

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

.1 Collision – the liquefied gas fuel containment system shall withstand the collision loads specified in 6.4.9.5.1 without deformation of the supports or the tank structure in way of the supports likely to endanger the tank and its supporting structure.
.2 Fire – the liquefied gas fuel containment systems shall sustain without rupture the rise in internal pressure specified in 6.7.3.1 under the fire scenarios envisaged therein.
.3 Flooded compartment causing buoyancy on tank – the anti-flotation arrangements shall sustain the upward force, specified in 6.4.9.5.2 and there shall be no endangering plastic deformation to the hull. Plastic deformation may occur in the fuel containment system provided it does not endanger the safe evacuation of the ship. (IGF Code, 6.4.1.6)

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. (IGF Code, 6.4.1.7)

6.4.1.8 An inspection/survey plan for the liquefied gas fuel containment system shall be developed and approved by the Administration. The inspection/survey plan shall identify aspects to be examined and/or validated during surveys throughout the liquefied gas fuel containment system's life and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting liquefied gas fuel containment system design parameters. The inspection/survey plan may include specific critical locations as per 6.4.12.2.8 or 6.4.12.2.9. (IGF Code, 6.4.1.8)

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. (IGF Code, 6.4.1.9)

6.4.2 Liquefied gas fuel containment safety principles (IGF Code, 6.4.2)

6.4.2.1 The containment systems shall be provided with a complete secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level. (IGF Code, 6.4.2.1)

For LPG, no secondary barrier should be required where the fuel temperature at atmospheric pressure is at or above - 10°C. Where the fuel temperature at atmospheric pressure is not below -55°C, the hull structure may act as a secondary barrier. (MSC.1/Circ.1666, 6.3.4)

6.4.2.2 The size and configuration or arrangement of the secondary barrier may be reduced or omitted where an equivalent level of safety can be demonstrated in accordance with 6.4.2.3 to 6.4.2.5 as applicable. (IGF Code, 6.4.2)

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

The arrangements shall comply with the following:

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

.2 failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank. (IGF Code, 6.4.2)

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. (IGF Code, 6.4.2)

6.4.2.5 For independent tanks requiring full or partial secondary barrier, means for safely disposing of leakages from the tank shall be arranged. (IGF Code, 6.4.2)

6.4.3 Secondary barriers in relation to tank types

Secondary barriers in relation to the tank types defined in 6.4.15 shall be provided in accordance with the following table. (IGF Code, 6.4.3)

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

6.4.4 Design of secondary barriers

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

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

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

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

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

.5 the methods required in 6.4.4.4 shall be approved by the Administration and shall include, as a minimum:

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

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

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

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

.6 the secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°. (IGF Code, 6.4.4)

6.4.5 Partial secondary barriers and primary barrier small leak protection system (IGF Code, 6.4.5)

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

The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquefied gas fuel down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation. (IGF Code, 6.4.5)

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. (IGF Code, 6.4.5)

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. (IGF Code, 6.4.5)

6.4.5.4 For independent tanks for which the geometry does not present obvious locations for leakage to collect, the partial secondary barrier shall also fulfil its functional requirements at a nominal static angle of trim. (IGF Code, 6.4.5)

6.4.6 Supporting arrangements (IGF Code, 6.4.6)

6.4.6.1 The liquefied gas fuel tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 6.4.9.2 to 6.4.9.5, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull. (IGF Code, 6.4.6.1)

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. (IGF Code, 6.4.6.2)

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. (IGF Code, 6.4.6.3)

6.4.7 Associated structure and equipment (IGF Code, 6.4.7)

6.4.7.1 Liquefied gas fuel containment systems shall be designed for the loads imposed by associated structure and equipment. This includes pump towers, liquefied gas fuel domes, liquefied gas fuel pumps and piping, stripping pumps and piping, nitrogen piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges). (IGF Code, 6.4.7.1)

6.4.8 Thermal insulation (IGF Code, 6.4.8)

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

6.4.9 Design loads (IGF Code, 6.4.9)

6.4.9.1 General (IGF Code, 6.4.9.1)

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

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. (IGF Code, 6.4.9.1.2)

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. (IGF Code, 6.4.9.1.3)

6.4.9.2 Permanent loads (IGF Code, 6.4.9.2)

6.4.9.2.1 Gravity loads

The weight of tank, thermal insulation, loads caused by towers and other attachments shall be considered. (IGF Code, 6.4.9.2.1)

6.4.9.2.2 Permanent external loads

Gravity loads of structures and equipment acting externally on the tank shall be considered. (IGF Code, 6.4.9.2.2)

6.4.9.3 Functional loads (IGF Code, 6.4.9.3)

6.4.9.3.1 Loads arising from the operational use of the tank system shall be classified as functional loads. (IGF Code, 6.4.9.3.1)

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. (IGF Code, 6.4.9.3.2)

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

.1 internal pressure
.2 external pressure
.3 thermally induced loads
.4 vibration
.5 interaction loads
.6 loads associated with construction and installation
.7 test loads
.8 static heel loads
.9 weight of liquefied gas fuel
.10 sloshing
.11 wind impact, wave impacts and green sea effect for tanks installed on open deck. (IGF Code, 6.4.9.3.3)

6.4.9.3.3.1 Internal pressure

.1 In all cases, including 6.4.9.3.3.1.2, P_0 shall not be less than MARVS.

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

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

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

.3 Subject to special consideration by the Administration and to the limitations given in 6.4.15 for the various tank types, a vapour pressure P_h higher than P_0 may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.

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

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

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

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

$$P_{eq1} = P_0 + \left(P_{gd}\right)_{\max} \ \ [\text{MPa}],$$

$$P_{eq2} = P_h + \left(P_{gd\ site}\right)_{\max} \ \ [\text{MPa}].$$

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

$$P_{gd} = \alpha_\beta Z_\beta (\rho/(1.02\times10^5)) \ \ [\text{MPa}]$$

where:

α_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β; (see figure 6.4.1).

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

Z_β = largest liquid height [m] above the point where the pressure is to be determined measured from the tank shell in the β direction (see figure 6.4.2).

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

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

where:

V_t = tank volume without any domes; and

FL = filling limit according to 6.8.

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

The direction that gives the maximum value $(P_{gd})_{max}$ or $(P_{gd\ site})_{max}$ 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. (IGF Code, 6.4.9.3.3.1)

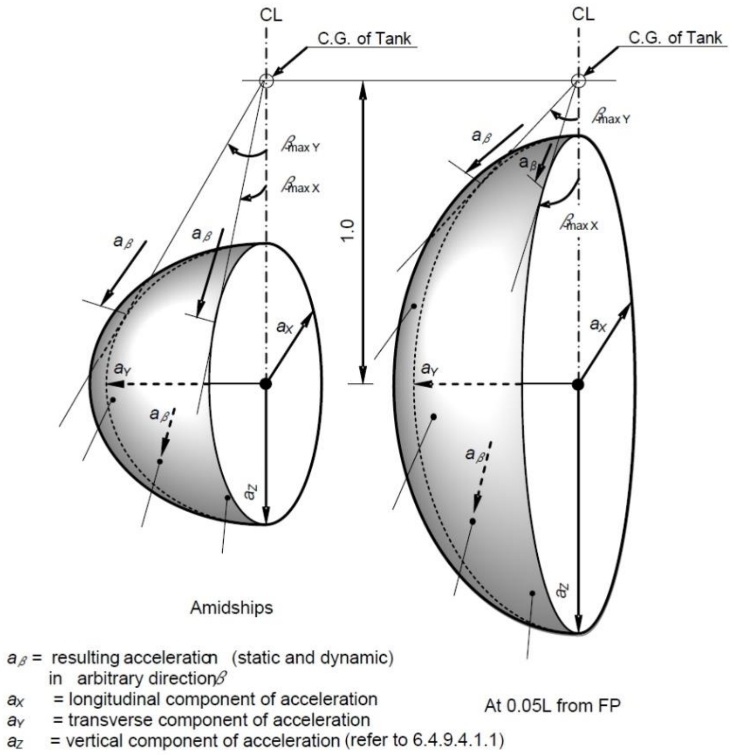


Figure 6.4.1. Acceleration ellipsoid

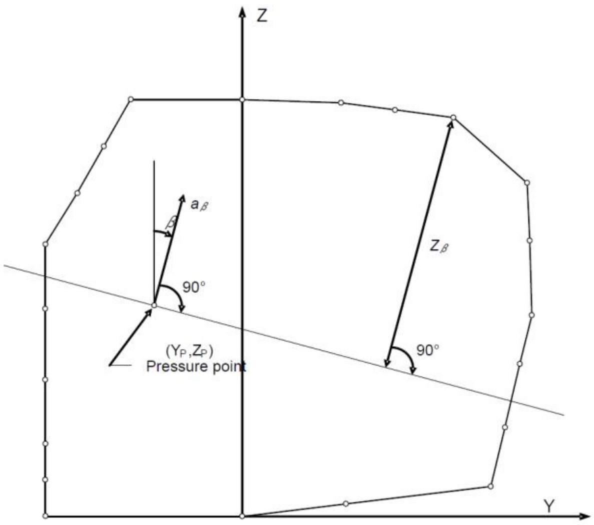


Figure 6.4.2. Determination of internal pressure heads

6.4.9.3.3.2 External pressure

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected. (IGF Code, 6.4.9.3.3.2)

6.4.9.3.3.3 Thermally induced loads (IGF Code, 6.4.9.3.3.3)

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. (IGF Code, 6.4.9.3.3.3.1)

6.4.9.3.3.3.2 Stationary thermally induced loads shall be considered for liquefied gas fuel containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see paragraph 6.9.2). (IGF Code, 6.4.9.3.3.3.2)

6.4.9.3.3.4 Vibration

The potentially damaging effects of vibration on the liquefied gas fuel containment system shall be considered (IGF Code, 6.4.9.3.3.4)

6.4.9.3.3.5 Interaction loads

The static component of loads resulting from interaction between liquefied gas fuel containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered. (IGF Code, 6.4.9.3.3.5)

6.4.9.3.3.6 Loads associated with construction and installation

Loads or conditions associated with construction and installation shall be considered, e.g. lifting. (IGF Code, 6.4.9.3.3.6)

6.4.9.3.3.7 Test loads

Account shall be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in 16.5. (IGF Code, 6.4.9.3.3.7)

6.4.9.3.3.8 Static heel loads

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30°shall be considered. (IGF Code, 6.4.9.3.3.8)

6.4.9.3.3.9 Other loads

Any other loads not specifically addressed, which could have an effect on the liquefied gas fuel containment system, shall be taken into account. (IGF Code, 6.4.9.3.3.9)

6.4.9.4 Environmental loads (IGF Code, 6.4.9.4)

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. (IGF Code, 6.4.9.4.1)

6.4.9.4.1.1 Loads due to ship motion

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

.1 vertical acceleration: motion accelerations of heave, pitch and, possibly roll (normal to the ship base);
.2 transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and
.3 longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

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

* Refer to section 4.28.2.1 of the *Rules for the Construction and Classification of Gas Tankers* (IGC Code) for guidance formulae for acceleration components.

Ships for restricted service may be given special consideration. (IGF Code, 6.4.9.4.1.1)

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. (IGF Code, 6.4.9.4.1.2)

6.4.9.4.1.3 Sloshing loads

The sloshing loads on a liquefied gas fuel containment system and internal components shall be evaluated for the full range of intended filling levels. (IGF Code, 6.4.9.4.1.3)

6.4.9.4.1.4 Snow and ice loads

Snow and icing shall be considered, if relevant. (IGF Code, 6.4.9.4.1.4)

6.4.9.4.1.5 Loads due to navigation in ice

Loads due to navigation in ice shall be considered for ships intended for such service. (IGF Code, 6.4.9.4.1.5)

6.4.9.4.1.6 Green sea loading

Account shall be taken to loads due to water on deck. (IGF Code, 6.4.9.4.1.6)

6.4.9.4.1.7 Wind loads

Account shall be taken to wind generated loads as relevant. (IGF Code, 6.4.9.4.1.7)

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. (IGF Code, 6.4.9.5)

6.4.9.5.1 Collision load

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

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

Special consideration should be given to ships with Froude number (F_n) > 0.4. (IGF Code, 6.4.9.5.1)

6.4.9.5.2 Loads due to flooding on ship

For independent tanks, loads caused by the buoyancy of a fully submerged empty tank shall be considered in the design of anti-flotation chocks and the supporting structure in both the adjacent hull and tank structure. (IGF Code, 6.4.9.5.2)

6.4.10 Structural integrity (IGF Code, 6.4.10)

6.4.10.1 General (IGF Code, 6.4.10.1)

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. (IGF Code, 6.4.10.1.1)

6.4.10.1.2 The structural integrity of liquefied gas fuel containment systems can be demonstrated by compliance with 6.4.15, as appropriate for the liquefied gas fuel containment system type. (IGF Code, 6.4.10.2)

6.4.10.1.3 For other liquefied gas fuel containment system types, that are of novel design or differ significantly from those covered by 6.4.15, the structural integrity shall be demonstrated by compliance with 6.4.16. (IGF Code, 6.4.10.3)

6.4.11 Structural analysis (IGF Code, 6.4.11)

6.4.11.1 Analysis (IGF Code, 6.4.11.1)

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

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. (IGF Code, 6.4.11.1.2)

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. (IGF Code, 6.4.11.1.3)

6.4.11.2 **Load scenarios** (IGF Code, 6.4.11.2)

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. (IGF Code, 6.4.11.2.1)

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

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 $\tau_{yz.st}$ are static stresses; and

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

each shall be determined separately from acceleration components and hull strain components due to deflection and torsion. (IGF Code, 6.4.11.2.3)

6.4.12 Design conditions

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this Chapter, and the load scenarios are covered by 6.4.11.2. (IGF Code, 6.4.12)

6.4.12.1 **Ultimate design condition** (IGF Code, 6.4.12.1)

6.4.12.1.1 Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of this *Publication* (Code):

.1 Plastic deformation and buckling shall be considered.

.2 Analysis shall be based on characteristic load values as follows:

Permanent loads	Expected values
Functional loads	Specified values
Environmental loads	For wave loads: most probable largest load encountered during 10^8 wave encounters.

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

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

.2 R_m = specified minimum tensile strength at room temperature (N/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 R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in liquefied gas fuel containment systems.

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

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

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

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

The above values shall be calculated as described in 6.4.11.2.3.

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

.6 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria. (IGF Code, 6.4.12.1.1)

6.4.12.2 Fatigue Design Condition

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

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

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

where:

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

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

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

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

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 *Cw* values specified in 6.4.12.2.7 to 6.4.12.2.9.

.5 Analysis shall be based on characteristic load values as follows:

Permanent loads	Expected values
Functional loads	Specified values or specified history
Environmental loads	Expected load history, but not less than 10^8 cycles.

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

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

.1 crack propagation paths in the structure, where necessitated by 6.4.12.2.7 to 6.4.12.2.9, as applicable;
.2 crack growth rate;
.3 the time required for a crack to propagate to cause a leakage from the tank;
.4 the size and shape of through thickness cracks; and
.5 the time required for detectable cracks to reach a critical state after penetration through the thickness.

The fracture mechanics are in general based on crack growth data taken as a mean value plus two standard deviations of the test data. Methods for fatigue crack growth analysis and fracture mechanics shall be based on recognized standards.

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

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

The arrangements shall comply with 6.4.12.2.7 to 6.4.12.2.9 as applicable.

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

C_w shall be less than or equal to 0.5.

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

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

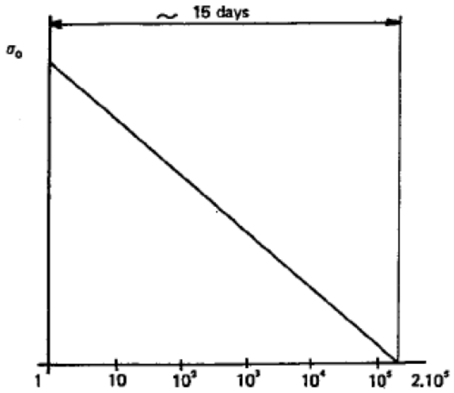
C_w shall be less than or equal to 0.5.

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

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

C_w shall be less than or equal to 0.1.

Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three (3) times the lifetime of the tank. (IGF Code, 6.4.12.2)



Response cycles

σ_0 = most probable maximum stress over the life of the ship
Response cycle scale is logarithmic; the value of 2.10^5 is given as an example of estimate.

Figure 6.4.3. Simplified load distribution

6.4.12.3 Accidental design condition (IGF Code, 6.4.12.3)

6.4.12.3.1 The accidental design condition is a design condition for accidental loads with extremely low probability of occurrence. (IGF Code, 6.4.12.3.1)

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. (IGF Code, 6.4.12.3.2)

6.4.13 Materials and construction (IGF Code, 6.4.13)

6.4.13.1 Materials (IGF Code, 6.4.13.1)

6.4.13.1.1 Materials forming ship structure (IGF Code, 6.4.13.1.1)

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

- **.1** The primary barrier of all tanks shall be assumed to be at the liquefied gas fuel temperature.
- **.2** In addition to .1 above, where a complete or partial secondary barrier is required it shall be assumed to be at the liquefied gas fuel temperature at atmospheric pressure for any one tank only.
- **.3** For worldwide service, ambient temperatures shall be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and conversely, lower values may be imposed by the Administration for ships trading to areas where lower temperatures are expected during the winter months.
- **.4** Still air and sea water conditions shall be assumed, i.e. no adjustment for forced convection.
- **.5** Degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations as defined in 6.4.13.3.6 and 6.4.13.3.7 shall be assumed.
- **.6** The cooling effect of the rising boil-off vapour from the leaked liquefied gas fuel shall be taken into account where applicable.
- **.7** Credit for hull heating may be taken in accordance with 6.4.13.1.1.3, provided the heating arrangements are in compliance with 6.4.13.1.1.4.
- **.8** No credit shall be given for any means of heating, except as described in 6.4.13.1.1.3.
- **.9** For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade. (IGF Code, 6.4.13.1.1.1)

6.4.13.1.1.2 The materials of all hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of liquefied gas fuel temperature, shall be in accordance with table 7.5. This includes hull structure supporting the liquefied gas fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members. (IGF Code, 6.4.13.1.1.2)

6.4.13.1.1.3 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in table 7.5. In the calculations required in 6.4.13.1.1.1, credit for such heating may be taken in accordance with the following principles:

.1 for any transverse hull structure;
.2 for longitudinal hull structure referred to in 6.4.13.1.1.2 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of plus 5°C for air and 0°C for seawater with no credit taken in the calculations for heating; and
.3 as an alternative to 6.4.13.1.1.3.2, for longitudinal bulkhead between liquefied gas fuel tanks, credit may be taken for heating provided the material remain suitable for a minimum design temperature of minus 30°C, or a temperature 30°C lower than that determined by 6.4.13.1.1.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation 11-1/3-1 for both when those bulkhead(s) are considered effective and not. (IGF Code, 6.4.13.1.1.3)

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

.1 the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to no less than 100% of the theoretical heat requirement;
.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 6.4.13.1.1.3.1 shall be supplied from the emergency source of electrical power; and
.3 the design and construction of the heating system shall be included in the approval of the containment system by the Administration. (IGF Code, 6.4.13.1.1.4)

6.4.13.2 Materials of primary and secondary barriers (IGF Code, 6.4.13.2)

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. (IGF Code, 6.4.13.2.1)

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

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

.1 compatibility with the liquefied gas fuels;
.2 ageing;
.3 mechanical properties;
.4 thermal expansion and contraction;
.5 abrasion;
.6 cohesion;
.7 resistance to vibrations;
.8 resistance to fire and flame spread; and
.9 resistance to fatigue failure and crack propagation. (IGF Code, 6.4.13.2.3)

* Refer to section 6.4.16

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 minus 196°C. (IGF Code, 6.4.13.2.4)

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. (IGF Code, 6.4.13.2.5)

6.4.13.2.6 Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier. (IGF Code, 6.4.13.2.6)

6.4.13.3 Thermal insulation and other materials used in liquefied gas fuel containment systems (IGF Code, 6.4.13.3)

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. (IGF Code, 6.4.13.3.1)

6.4.13.3.2 Thermal insulation and other materials used in liquefied gas fuel containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the liquefied gas fuels;
.2 solubility in the liquefied gas fuel;
.3 absorption of the liquefied gas fuel;
.4 shrinkage;
.5 ageing;
.6 closed cell content;
.7 density;
.8 mechanical properties, to the extent that they are subjected to liquefied gas fuel and other loading effects, thermal expansion and contraction;
.9 abrasion;
.10 cohesion;
.11 thermal conductivity;
.12 resistance to vibrations;
.13 resistance to fire and flame spread; and
.14 resistance to fatigue failure and crack propagation. (IGF Code, 6.4.13.3.2)

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. (IGF Code, 6.4.13.3.3)

6.4.13.3.4 Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal. (IGF Code, 6.4.13.3.4)

6.4.13.3.5 Thermal insulation that does not meet recognized standards for fire resistance may be used in fuel storage hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal. (IGF Code, 6.4.13.3.5)

6.4.13.3.6 Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples. (IGF Code, 6.4.13.3.6)

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. (IGF Code, 6.4.13.3.7)

6.4.14 Construction processes (IGF Code, 6.4.14)

6.4.14.1 Weld joint design (IGF Code, 6.4.14.1)

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. (IGF Code, 6.4.14.1.1)

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. For connections of tank shell to a longitudinal bulkhead of type C bilobe tanks, tee welds of the full penetration type may be accepted.

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

.2 The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to the Administration. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds. (IGF Code, 6.4.14.1.1)

6.4.14.2 Design for gluing and other joining processes (IGF Code, 6.4.14.2)

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. (IGF Code, 6.4.14.2.1)

6.4.15 Tank types (IGF Code, 6.4.15)

6.4.15.1 Type A independent tanks (IGF Code, 6.4.15.1)

6.4.15.1.1 Design basis (IGF Code, 6.4.15.1.1)

6.4.15.1.1.1 Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with the requirements of the Administration. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_0 shall be less than 0,07 MPa. (IGF Code, 6.4.15.1.1.1)

6.4.15.1.1.2 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed in accordance with 6.4.4. (IGF Code, 6.4.15.1.1.2)

6.4.15.1.2 Structural analysis (IGF Code, 6.4.15.1.2)

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. (IGF Code, 6.4.15.1.2.1)

6.4.15.1.2.2 For parts, such as structure in way of supports, not otherwise covered by the regulations in this Code, stresses shall be determined by direct calculations, taking into account the loads referred to in 6.4.9.2 to 6.4.9.5 as far as applicable, and the ship deflection in way of supports. (IGF Code, 6.4.15.2.2)

6.4.15.1.2.3 The tanks with supports shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads. (IGF Code, 6.4.15.2.3)

6.4.15.1.3 Ultimate design condition (IGF Code, 6.4.15.1.3)

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 Rm and Re are defined in 6.4.12.1.1.3. However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c, as defined in 6.4.12.1.1.4, may be increased over that indicated above to a stress acceptable to the Administration. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/liquefied gas fuel tank interaction forces due to the deflection of the hull structure and liquefied gas fuel tank bottoms. (IGF Code, 6.4.15.1.3.1)

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

6.4.15.1.3.3 The liquefied gas fuel tank structure shall be reviewed against potential buckling. (IGF Code, 6.4.15.1.3.3)

6.4.15.1.4 Accidental design condition (IGF Code, 6.4.15.1.4)

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

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. (IGF Code, 6.4.15.1.4.2)

6.4.15.2 Type B independent tanks (IGF Code, 6.4.15.2)

6.4.15.2.1 Design basis (IGF Code, 6.4.15.2.1)

6.4.15.2.1.1 Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks) the design vapour pressure P_0 shall be less than 0.07 MPa. (IGF Code, 6.4.15.2.1.1)

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

6.4.15.2.2 Structural analysis (IGF Code, 6.4.15.2.2)

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

.1 plastic deformation;
.2 buckling;
.3 fatigue failure; and
.4 crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, shall be carried out. (IGF Code, 6.4.15.2.2.1)

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. (IGF Code, 6.4.15.2.2.2)

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. (IGF Code, 6.4.15.2.2.3)

6.4.15.2.3 Ultimate design condition (IGF Code, 6.4.15.2.3)

6.4.15.2.3.1 Plastic deformation

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

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

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

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

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

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

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;

σ_g = equivalent secondary stress;
f = the lesser of (R_m/A) or (R_e/B); and
F = the lesser of (R_m/C) or (R_e/D),

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

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

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

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

.1 for nickel steels and carbon-manganese steels, the lesser of $R_m/2$ or $R_e/1.2$;
.2 for austenitic steels, the lesser of $R_m/2.5$ or $R_e/1.2$; and
.3 for aluminium alloys, the lesser of $R_m/2.5$ or $R_e/1.2$.

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

The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks. (IGF Code, 6.4.15.2.3.1)

6.4.15.2.3.2 Buckling

Buckling strength analyses of liquefied gas fuel tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable. (IGF Code, 6.4.15.2.3.2)

6.4.15.2.3.3 Fatigue design condition (IGF Code, 6.4.15.2.3.3)

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. (IGF Code, 6.4.15.2.3.3.1)

6.4.15.2.3.3.2 Fatigue analysis shall consider construction tolerances. (IGF Code, 6.4.15.2.3.3.2)

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. (IGF Code, 6.4.15.2.3.3.3)

6.4.15.2.3.4 Accidental design condition (IGF Code, 6.4.15.2.3.4)

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

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

6.4.15.2.3.5 Marking

Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers. (IGF Code, 6.4.15.2.3.5)

6.4.15.2.3.6 Stress categories

For the purpose of stress evaluation, stress categories are defined in this section as follows:

.1 *Normal stress* is the component of stress normal to the plane of reference.

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

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

.4 *Shear stress* is the component of the stress acting in the plane of reference.

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

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

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

$$S_1 \leq 0.5\sqrt{Rt}$$

$$S_1 \geq 2.5\sqrt{Rt}$$

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds 1.1/;

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

R = mean radius of the vessel;

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

f = allowable primary general membrane stress.

.8 *Secondary stress* is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur. (IGF Code, 6.4.15.2.3.5)

6.4.15.3 Type C independent tanks (IGF Code, 6.4.15.3)

6.4.15.3.1 Design basis (IGF Code, 6.4.15.3.1)

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. (IGF Code, 6.4.15.3.1.1)

6.4.15.3.1.2 The design vapour pressure shall not be less than:

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

where:

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

with:

σ_m = design primary membrane stress;

$\Delta\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$) and equal to:
- 55 N/mm² for ferritic-perlitic, martensitic and austenitic steel;
- 25 N/mm² for aluminium alloy (5083-O);

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

h, $0.75b$ 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];
ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature. (IGF Code, 6.4.15.3.1.2)

6.4.15.3.2 **Shell thickness** (IGF Code, 6.4.15.3.2)

6.4.15.3.2.1 In considering the shell thickness the following apply:

.1 for pressure vessels, the thickness calculated according to 6.4.15.3.2.4 shall be considered as a minimum thickness after forming, without any negative tolerance;

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

.3 the welded joint efficiency factor to be used in the calculation according to 6.4.15.3.2.4 shall be 0.95 when the inspection and the non-destructive testing referred to in 16.3.6.4 are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels the Administration may accept partial non-destructive examinations, but not less than those of 16.3.6.4, depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 shall be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint. (IGF Code, 6.4.15.3.2.1)

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. (IGF Code, 6.4.15.3.2.2)

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:

$$P_e = P_1 + P_2 + P_3 + P_4 \text{ [MPa]}$$

where:

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

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

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

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$. (IGF Code, 6.4.15.3.2.3)

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

The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 6.4.9.3.3.1, including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with a recognized standard acceptable to the Administration. (IGF Code, 6.4.15.3.2.4)

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

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

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

.3 if required by the Administration, secondary stresses and thermal stresses shall be specially considered. (IGF Code, 6.4.15.3.2.5)

6.4.15.3.3 Ultimate design condition (IGF Code, 6.4.15.3.3)

6.4.15.3.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$$\sigma_m \le f$$

$$\sigma_L \le 1.5f$$

$$\sigma_b \le 1.5f$$

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

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

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

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

where:
σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress; and
f = the lesser of R_m/A or R_e/B,

with R_m and R_e as defined in 6.4.12.1.1.3. With regard to the stresses σ_m, σ_L, σ_g and σ_b, see also the definition of stress categories in 6.4.15.2.3.6. The values *A* and *B* shall have at least the following minimum values: (IGF Code, 6.4.15.3.3.1)

	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. (IGF Code, 6.4.15.3.3.2)

6.4.15.3.4 Fatigue design condition (IGF Code, 6.4.15.3.4)

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

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. (IGF Code, 6.4.15.3.4.2)

6.4.15.3.5 Accidental design condition (IGF Code, 6.4.15.3.5)

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

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. (IGF Code, 6.4.15.3.5.2)

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. (IGF Code, 6.4.15.3.6)

6.4.15.4 Membrane tanks (IGF Code, 6.4.15.4)

6.4.15.4.1 Design basis (IGF Code, 6.4.15.4.1)

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. (IGF Code, 6.4.15.4.1.1)

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. (IGF Code, 6.4.15.4.1.2)

6.4.15.4.1.3 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed according to 6.4.4. (IGF Code, 6.4.15.4.1.3)

6.4.15.4.1.4 The design vapour pressure P_0 shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_0 may be increased to a higher value but less than 0.070 MPa. (IGF Code, 6.4.15.4.1.4)

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. (IGF Code, 6.4.15.4.1.5)

6.4.15.4.1.6 The thickness of the membranes shall normally not exceed 10 mm. (IGF Code, 6.4.15.4.1.6)

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

6.4.15.4.2 **Design considerations** (IGF Code, 6.4.15.4.2)

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

.1 Ultimate design events:

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

.2 Fatigue design events:

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

.3 Accident design events:

- **.1** accidental mechanical damage (such as dropped objects inside the tank while in service);
- **.2** accidental over pressurization of thermal insulation spaces;

.3 accidental vacuum in the tank; and

.4 water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable. (IGF Code, 6.4.15.4.2.1)

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. (IGF Code, 6.4.15.4.2.2)

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 inter-barrier space, a possible vacuum in the liquefied gas fuel tank, the sloshing effects, to hull vibration effects, or any combination of these events. (IGF Code, 6.4.15.4.3)

6.4.15.4.4 Structural analyses (IGF Code, 6.4.15.4.4)

6.4.15.4.4.1 Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the liquefied gas fuel containment and associated structures and equipment noted in 6.4.7 shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the liquefied gas fuel containment system. (IGF Code, 6.4.15.4.4.1)

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. (IGF Code, 6.4.15.4.4.2)

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. (IGF Code, 6.4.15.4.4.3)

6.4.15.4.5 Ultimate design condition (IGF Code, 6.4.15.4.5)

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. (IGF Code, 6.4.15.4.5.1)

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. (IGF Code, 6.4.15.4.5.2)

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

6.4.15.4.6 Fatigue design condition (IGF Code, 6.4.15.4.6)

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. (IGF Code, 6.4.15.4.6.1)

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

.1 the significance of the structural components with respect to structural integrity; and
.2 availability for inspection. (IGF Code, 6.4.15.4.6.2)

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. (IGF Code, 6.4.15.4.6.3)

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

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

6.4.15.4.7 **Accidental design condition** (IGF Code, 6.4.15.4.7)

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

6.4.15.4.7.2 Additional relevant accidental scenarios shall be determined based on a risk analysis (see 4.2). Particular attention shall be paid to securing devices inside of tanks. (IGF Code, 6.4.15.4.7.2)

6.4.16 **Limit state design for novel concepts** (IGF Code, 6.4.16)

6.4.16.1 Fuel containment systems that are of a novel configuration that cannot be designed using section 6.4.15 shall be designed using this section and 6.4.1 to 6.4.14, as applicable. Fuel containment system design according to this section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using 6.4.15. (IGF Code, 6.4.16.1)

6.4.16.2 The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 6.4.1.6. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations. (IGF Code, 6.4.16.2)

6.4.16.3 For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:

.1 Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.
.2 Fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.
.3 Accident limit states (ALS), which concern the ability of the structure to resist accidental situations. (IGF Code, 6.4.16.3)

6.4.16.4 The procedure and relevant design parameters of the limit state design shall comply with the *Standards for the Use of limit state methodologies in the design of fuel containment systems of novel configuration (LSD Standard)*, as set out in the Annex 1 of this *Publication*. (IGF Code, 6.4.16.4)

6.5 Portable liquefied gas fuel tanks (IGF Code, 6.5)

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

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

.1 mechanical protection of the tanks depending on location and cargo operations;
.2 if located on open deck: spill protection and water spray systems for cooling; and
.3 if located in an enclosed space: the space is to be considered as a tank connection space. (IGF Code, 6.5.2)

6.5.3 Portable fuel tanks shall be secured to the deck while connected to the ship systems. The arrangement for supporting and fixing the tanks shall be designed for the maximum expected static and dynamic inclinations, as well as the maximum expected values of acceleration, taking into account the ship characteristics and the position of the tanks. (IGF Code, 6.5.3)

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

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

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. (IGF Code, 6.5.6)

6.5.7 The pressure relief system of portable tanks shall be connected to a fixed venting system. (IGF Code, 6.5.7)

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

6.5.9 Safe access to tank connections for the purpose of inspection and maintenance shall be ensured. (IGF Code, 6.5.9)

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

.1 with the exception of the pressure relief system in 6.5.7 each portable tank shall be capable of being isolated at any time;
.2 isolation of one tank shall not impair the availability of the remaining portable tanks; and
.3 the tank shall not exceed its filling limits as given in 6.8. (IGF Code, 6.5.10)

6.6 CNG fuel containment (IGF Code, 6.6)

Note:
The provision of 6.6 (of the IGF Code) does not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 6.3.5)

6.6.1 The storage tanks to be used for CNG shall be certified and approved by the Administration. (IGF Code, 6.6.1)

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

6.6.3 Adequate means shall be provided to depressurize the tank in case of a fire which can affect the tank. (IGF Code, 6.6.3)

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

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

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

.3 a fixed fire-extinguishing system is installed in the enclosed spaces containing the CNG storage. Special consideration should be given to the extinguishing of jet-fires. (IGF Code, 6.6.4)

6.7 Pressure relief system (IGF Code, 6.7)

6.7.1 General (IGF Code, 6.7.1)

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, and tank connection spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 shall be independent of the pressure relief systems. (IGF Code, 6.7.1.1)

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. (IGF Code, 6.7.1.2)

6.7.2 Pressure relief systems for liquefied gas fuel tanks (IGF Code, 6.7.2)

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

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

6.7.2.3 Interbarrier spaces shall be provided with pressure relief devices* For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs. (IGF Code, 6.7.2.3)

* Refer to IACS UI GC9, Rev.1 – *Guidance for sizing pressure relief systems for interbarrier spaces*. See PRS' *Rules for the Classification and Construction of Sea-going Gas Tankers* – interpretation UI GC9 under 8.2.2.

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. (IGF Code, 6.7.2.4)

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

.1 PRVs on fuel tanks with a design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation;
.2 the effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs;
.3 PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and
.4 sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage. (IGF Code, 6.7.2.5)

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

.1 procedures shall be provided and included in the operation manual;
.2 the procedures shall allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks shall be included to this effect; and
.3 isolation of the PRV shall be carried out under the supervision of the master. This action shall be recorded in the ship's log, and at the PRV. (IGF Code, 6.7.2.6)

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. (IGF Code, 6.7.2.7)

Additionally for LPG, vent exits should be so located that the following are ensured*:

.4 escaped LPG gas does not escape to non-hazardous areas through the opening around the vent exit;
.5 escaped LPG gas is not trapped by any structure on an open deck; and
.6 escaped LPG gas does not form a flammable atmosphere in the way of exhaust gas outlets and other ignition sources. (MSC.1/Circ.1666, 6.3.6)

* According to a gas dispersion analysis, if required by the risk assessment (see 4.2).

6.7.2.8 The outlet from the pressure relief valves shall normally be located at least 10 m from the nearest:

.1 air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and
.2 exhaust outlet from machinery installations. (IGF Code, 6.7.2.8)

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

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. (IGF Code, 6.7.2.10)

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. (IGF Code, 6.7.2.11)

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. (IGF Code, 6.7.2.12)

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

6.7.2.14 For LPG, in addition, the vent piping system should be fitted with an inert gas purging interface. (MSC.1/Circ.1666, 6.3.7)

6.7.3 Sizing of pressure relieving system (IGF Code, 6.7.3)

6.7.3.1 Sizing of pressure relief valves (IGF Code, 6.7.3.1)

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*:

$$Q = FGA^{0.82} \ [m^3/s]$$

where:

Q = minimum required rate of discharge of air at standard conditions of 273.15 Kelvin (K) and 0.1013 MPa.

F = fire exposure factor for different liquefied gas fuel types:

- F = 1.0 for tanks without insulation located on deck;
- F = 0.5 for tanks above the deck when insulation is approved by the Administration. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);
- F = 0.5 for uninsulated independent tanks installed in holds;
- F = 0.2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);
- F = 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds); and
- F = 0.1 for membrane tanks.

For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck.

G = gas factor according to formula:

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

where:

T = temperature in Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L = latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D = a constant based on relation of specific heats *k* and is calculated as follows:

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

where:

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

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

M = molecular mass of the product.

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

A = external surface area of the tank (m^2), as for different tank types, as shown in figure 6.7.1 (IGF Code, 6.7.3.1.1)

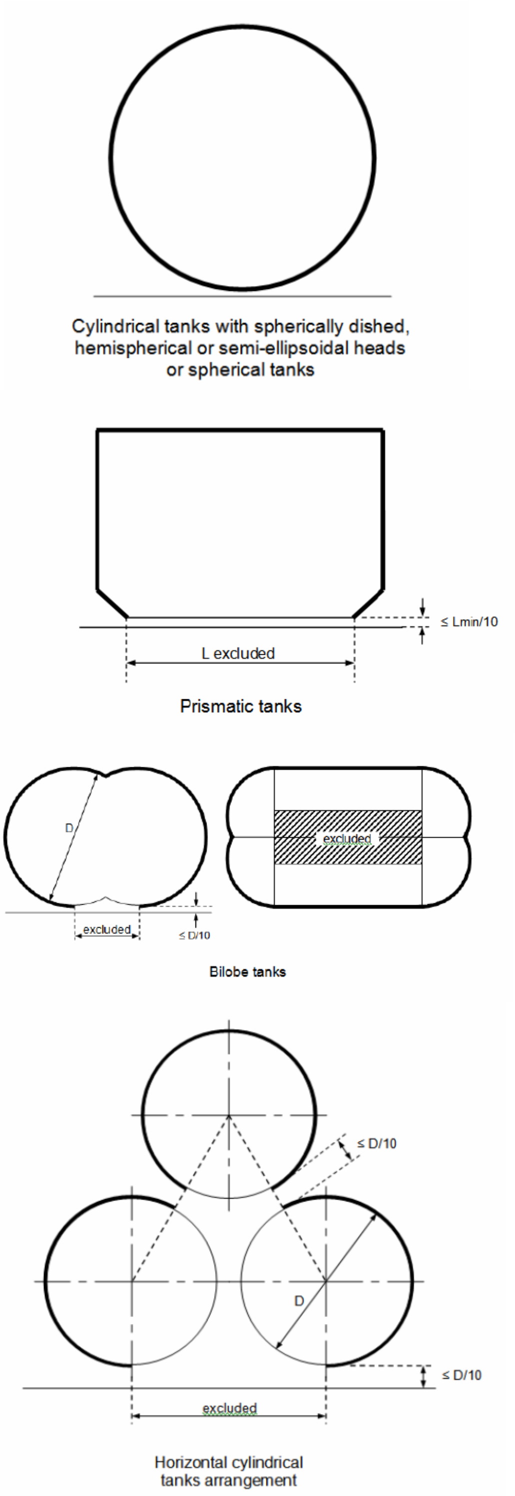


Figure 6.7.1

IACS and IMO interpretation:

For prismatic tanks:

1. *L_{min}, for non-tapered tanks, is the smaller of the horizontal dimensions of the flat bottom of the tank. For tapered tanks, as would be used for the forward tank, L min is the smaller of the length and the average width.*

2. *For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is equal to or less than $L_{min}/10$:*
A = external surface area minus flat bottom surface area.
3 . *For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than $L_{min}/10$:*
A = external surface area (IACS UI GF7 and MSC.1/Circ.1558)

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

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

$$F = 0.5 \text{ to } F = 0.25$$

$$F = 0.2 \text{ to } F = 0.1$$

The minimum fire factor is $F = 0.1$. (IGF Code, 6.7.3.1.2)

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

$$M_{air} = Q \times \rho_{air} \text{ [kg/s]}$$

where density of air ρ_{air} = 1.293 kg/m³ (air at 273.15 K, 0.1013 MPa). (IGF Code, 6.7.3.1.3)

6.7.3.2 Sizing of vent pipe system (IGF Code, 6.7.3.2)

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. (IGF Code, 6.7.3.2.1)

6.7.3.2.2 Upstream pressure losses

.1 the pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 6.7.3.1;
.2 pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and
.3 pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots. (IGF Code, 6.7.3.2.2)

6.7.3.2.3 Downstream pressure losses

.1 Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.
.2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, shall not exceed the following values:

.1 for unbalanced PRVs: 10% of MARVS;
.2 for balanced PRVs: 30% of MARVS; and
.3 for pilot operated PRVs: 50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted. (IGF Code, 6.7.3.2.3)

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

6.8 Loading limit for liquefied gas fuel tanks (IGF Code, 6.8)

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

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

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

where:

LL = loading limit as defined in 2.2.27, expressed in per cent;
FL = filling limit as defined in 2.2.16 expressed in per cent, here 98%;
ρ_R = relative density of fuel at the reference temperature; and
ρ_L = relative density of fuel at the loading temperature. (IGF Code, 6.8.1)

6.8.2 In cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. This also applies in cases where a second system for pressure maintenance is installed, (refer to 6.9). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in 6.8.1 shall be used. (IGF Code, 6.8.2)

IACS and IMO interpretation:

The alternative loading limit option given under 6.8.2 is understood to be an alternative to 6.8.1 and should only be applicable when the calculated loading limit using the formulae in 6.8.1 gives a lower value than 95%. (IACS UI GF16 and MSC.1/Circ.1591).

6.8.3 For ships constructed on or after 1 January 2024, in cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. (IGF Code, 6.8.2)

6.9 Maintaining of fuel storage condition (IGF Code, 6.9)

6.9.1 Control of tank pressure and temperature (IGF Code, 6.9.1)

IACS and IMO interpretation:

Liquefied gas fuel tanks' pressure and temperature shall be controlled and maintained within the design range at all times including after activation of the safety system required in 15.2.2 for a period of minimum 15 days. The activation of the safety system alone is not deemed as an emergency situation. (IACS UI GF8 and .MSC.1/Circ.1558)

6.9.1.1 With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature shall be maintained at all times within their design range by means acceptable to the Administration, e.g. by one of the following methods:

.1 reliquefaction of vapours;
.2 thermal oxidation of vapours;
.3 pressure accumulation; or
.4 liquefied gas fuel cooling.

The method chosen shall be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition, i.e. only power for domestic load is generated. (IGF Code, 6.9.1.1)

6.9.1.2 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations. (IGF Code, 6.9.1.2)

6.9.2 Design of systems (IGF Code, 6.9.2)

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

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. (IGF Code, 6.9.2.2)

6.9.3 Reliquefaction systems (IGF Code, 6.9.3)

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. (IGF Code, 6.9.3.1)

6.9.3.2 The reliquefaction system shall be arranged in one of the following ways:

.1 a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;
.2 an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;
.3 a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks; or
.4 if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases shall, as far as reasonably practicable, be disposed of without venting to atmosphere. (IGF Code, 6.9.3.2)

6.9.4 Thermal oxidation systems (IGF Code, 6.9.4)

6.9.4.1 Thermal oxidation can be done by either consumption of the vapours according to the regulations for consumers described in this *Publication* (Code) or in a dedicated gas combustion unit (GCU). It shall be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard, periods of slow steaming and/or no consumption from propulsion or other services of the ship shall be considered. (IGF Code, 6.9.4.1)

6.9.5 Compatibility (IGF Code, 6.9.5)

6.9.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel shall be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these shall be compatible with each other. (IGF Code, 6.9.5.1)

6.9.6 Availability of systems (IGF Code, 6.9.6)

6.9.6.1 The availability of the system and its supporting auxiliary services (fuel reception) 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. (IGF Code, 6.9.6.1)

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

6.10 Atmospheric control within the fuel containment system (IGF Code, 6.10)

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

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. (IGF Code, 6.10.2)

6.10.3 Gas sampling points shall be provided for each fuel tank to monitor the progress of atmosphere change. (IGF Code, 6.10.3)

6.10.4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship. (IGF Code, 6.10.4)

6.11 Atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks) (IGF Code, 6.11)

6.11.1 Inter-barrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days. Shorter periods may be considered by the Administration depending on the ship's service. (IGF Code, 6.11.1)

6.11.2 Alternatively, the spaces referred to in 6.11.1 requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided. (IGF Code, 6.11.2)

6.12 Environmental control of spaces surrounding type C independent tanks (IGF Code, 6.12)

6.12.1 Spaces surrounding liquefied gas fuel tanks shall be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This is only applicable for liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue. (IGF Code, 6.12.1)

6.13 Inerting (IGF Code, 6.13)

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

6.13.2 To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line shall be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve shall be installed between the double block and bleed arrangement and the fuel system. These valves shall be located outside non-hazardous spaces. (IGF Code, 6.13.2)

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

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. (IGF Code, 6.13.4)

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. (IGF Code, 6.13.5)

6.14 Inert gas production and storage on board (IGF Code, 6.14)

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

6.14.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the fuel containment system. (IGF Code, 6.14.2)

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. (IGF Code, 6.14.3)

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

- be fully welded;
- have only a minimum of flange connections as needed for fitting of valves; and
- be as short as possible. (IGF Code, 6.14.4)

7 MATERIAL AND GENERAL PIPE DESIGN (IGF Code, 7)

Notes:

1. See also, MSC.1/Circ.1622: *Guidelines for the acceptance of alternative metallic materials for cryogenic service in ships carrying liquefied gases in bulk and ships using gases or other low-flashpoint fuels*.
2. Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 7 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 7)

7.1 Goal

The goal of this Chapter is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved. (IGF Code, 7.1)

7.2 Functional requirements (IGF Code, 7.2)

7.2.1 This Chapter relates to functional requirements in 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply: (IGF Code, 7.2.1)

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. (IGF Code, 7.2.1.1)

7.2.1.2 Provision shall be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure. (IGF Code, 7.2.1.2)

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. (IGF Code, 7.2.1.3)

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. (IGF Code, 7.2.1.4)

7.3 Pipe design (IGF Code, 7.3)

7.3.1 General (IGF Code, 7.3.1)

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*.(IGF Code, 7.3.1.1)

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

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. (IGF Code, 7.3.1.2)

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

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

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. (IGF Code, 7.3.1.5)

7.3.2 Wall thickness (IGF Code, 7.3.2)

7.3.2.1 The minimum wall thickness shall be calculated as follows:

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

where:

t_0 = theoretical thickness

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

with:

P = design pressure [MPa] referred to in 7.3.3;
D = outside diameter [mm];
K = allowable stress [N/mm^2] referred to in 7.3.4; and
e = efficiency factory equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process;
b = allowance for bending [mm]. The value of b shall be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b shall be:

$$b = D \cdot t_0 / 2.5r \ [\text{mm}]$$

with:

r = mean radius of the bend [mm];
c = corrosion allowance [mm]. If corrosion or erosion is expected the wall thickness of the piping shall be increased over that required by other design regulations. This allowance shall be consistent with the expected life of the piping; and
a = negative manufacturing tolerance for thickness [%]. (IGF Code, 7.3.2.1)

7.3.2.2 The absolute minimum wall thickness shall be in accordance with a standard acceptable to the Administration. (IGF Code, 7.3.2.2)

7.3.3 Design condition (IGF Code, 7.3.3)

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

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, 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. (IGF Code, 7.3.3.1)

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

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

7.3.3.2 Piping, piping systems and components shall have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa. (IGF Code, 7.3.3.2)

7.3.4 Allowable stress (IGF Code, 7.3.4)

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

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

where:

R_m = specified minimum tensile strength at room temperature [N/mm^2]; and
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. (IGF Code, 7.3.4.1)

7.3.4.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by 7.3.2 or, if this is impracticable or would cause excessive local stresses, these loads shall be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supports, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise. (IGF Code, 7.3.4.2)

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

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

.1 stresses due to the weight of the piping system;
.2 acceleration loads when significant; and
.3 internal pressure and loads induced by hog and sag of the ship. (IGF Code, 7.3.4.4)

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. (IGF Code, 7.3.4.5)

7.3.5 Flexibility of piping (IGF Code, 7.3.5)

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

7.3.6 Piping fabrication and joining details (IGF Code, 7.3.6)

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. (IGF Code, 7.3.6.1)

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

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. (IGF Code, 7.3.6.3)

Note:
See also interpretation in 9.2.2.

7.3.6.4 Piping fabrication and joining details shall comply with the following: (IGF Code, 7.3.6.4)

7.3.6.4.1 Direct connections

- **.1** Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings shall be removed.
- **.2** Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than minus 55°C.
- **.3** Screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less. (IGF Code, 7.3.6.4.1)

7.3.6.4.2 Flanged connections

- **.1** Flanges in flange connections shall be of the welded neck, slip-on or socket welded type; and
- **.2** For all piping except open ended, the following restrictions apply:
  - **.1** For design temperatures colder than minus 55°C, only welded neck flanges shall be used; and
  - **.2** For design temperatures colder than minus 10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm. (IGF Code, 7.3.6.4.2)

7.3.6.4.3 Expansion joints

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

- **.1** if necessary, bellows shall be protected against icing;
- **.2** slip joints shall not be used except within the liquefied gas fuel storage tanks; and
- **.3** bellows shall normally not be arranged in enclosed spaces. (IGF Code, 7.3.6.4.3)

7.3.6.4.4 Other connections

Piping connections shall be joined in accordance with 7.3.6.4.1 to 7.3.6.4.3 but for other exceptional cases the Administration may consider alternative arrangements. (IGF Code, 7.3.6.4.4)

7.4 Materials (IGF Code, 7.4)

7.4.1 Metallic materials (IGF Code, 7.4.1)

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

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

Table 7.2: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to minus 55°C.

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

Table 7.4: Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to minus 165°C.

Table 7.5: Plates and sections for hull structures required by 6.4.13.1.1.2. (IGF Code, 7.4.1.1)

Table 7.1
Plates, pipes (seamless and welded) [1) 2)], sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C

CHEMICAL COMPOSITION AND HEAT TREATMENT		
▪ Carbon-manganese steel		
▪ Fully killed fine grain steel [6)]		
▪ Small additions of alloying elements by agreement with the Administration		
▪ Composition limits to be approved by the Administration		
▪ Normalized (N) or quenched and tempered (QT) [4)]		
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS		
Sampling frequency		
▪ Plates	Each “piece” to be tested	
▪ Sections and forgings	Each “batch” to be tested	
Mechanical properties		
▪ Tensile properties	Specified minimum yield stress $R_e \leq 410$ MPa [2) 5)]	
Toughness (Charpy V-notch test)		
▪ Plates	Transverse test pieces. Minimum average energy value (KV) 27 J	
▪ Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J	
▪ Test temperature	Thickness t [mm]	Test temperature [°C]
	$t \leq 20$	0
	$20 < t \leq 40$ [3)]	–20

Notes:

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

Table 7.2
Plates, sections and forgings [1)] for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to minus 55°C
Maximum thickness 25 mm [2)]

CHEMICAL COMPOSITION AND HEAT TREATMENT					
▪ Carbon-manganese steel					
▪ Fully killed, aluminium treated fine grain steel [6)]					
▪ Chemical composition (ladle analysis) [%]:					
C	Mn	Si	S	P	
0.16% max [3)]	0.70÷1.60	0.10÷0.50	0.025 max	0.025 max	
Optional additions: Alloys and grain refining elements may be generally in accordance with the following					
Ni	Cr	Mo	Cu	Nb	V
0.80 max	0.25 max	0.08 max	0.35 max	0.05 max	0.10% max
Al content total 0.020% min (Acid soluble 0.015 min %)					
▪ Normalized (N) or quenched and tempered (QT) [4)]					
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS					
Sampling frequency					
▪ Plates	Each "piece" to be tested				
▪ Sections and forgings	Each "batch" to be tested				
Mechanical properties					
▪ Tensile properties	Specified minimum yield stress $R_e \leq$ 410 MPa [5)]				
Toughness (Charpy V-notch test)					
▪ Plates	Transverse test pieces. Minimum average energy value (KV) 27 J				
▪ Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J				
▪ Test temperature	5°C below the design temperature or –20°C whichever is lower				

Notes:
1) The Charpy V-notch and chemical composition regulations for forgings may be specially considered by the Administration.
2) For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material thickness, t [mm]	Test temperature [°C]
$25 < t \leq 30$	10°C below design temperature or –20°C whichever is lower
$30 < t \leq 35$	15°C below design temperature or –20°C whichever is lower
$35 < t \leq 40$	20°C below design temperature
$40 < t$	Temperature approved by the Administration

The impact energy value (KV) shall be in accordance with the table for the applicable type of test specimen. Materials for 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 (CR) procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.
5) Materials with specified minimum yield stress (R_e) exceeding 410 MPa may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance:
For materials exceeding 25 mm in thickness for which the test temperature is –60°C or lower, the application of specially treated steels or steels in accordance with table 7.3 may be necessary.

Table 7.3
Plates, sections and forgings [1)] for fuel tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to minus 165°C [2)]
Maximum thickness 25 mm [3), 4)]

Minimum design temperature [°C]	Chemical composition [5)] and heat treatment	Impact test temperature [°C]
–60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6)]	–65
–65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6) 7)]	–70
–90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6) 7)]	–95
–105	5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6) 7) 8)]	–110
–165	9% nickel steel – double normalized and tempered or quenched and tempered [6)]	–196
–165	Austenitic steels, such as grades 304, 304L, 316, 316L, 321 and 347 – solution treated [9)]	–196
–165	Aluminium alloys, such as grade 5083 annealed	Not required
–165	Austenitic Fe-Ni alloy (36% nickel); Heat treatment as agreed	Not required
TENSILE AND IMPACT TEST REGULATIONS		
Sampling frequency		
▪ Plates	Each "piece" to be tested	
▪ Sections and forgings	Each "batch" to be tested	
Toughness (Charpy V-notch test)		
▪ Plates	Transverse test pieces. Minimum average energy value (KV) 27 J	
▪ Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J	

Notes:
1) The impact test required for forgings used in critical applications shall be subject to special consideration by the Administration.
2) The regulations for design temperatures below –165°C shall be specially agreed with the Administration.
3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thickness greater than 25 mm, the impact tests shall be conducted as follows:

Material thickness, t [mm]	Test temperature [°C]
$25 < t \le 30$	10°C below design temperature
$30 < t \le 35$	15°C below design temperature
$35 < t \le 40$	20°C below design temperature

The energy value (KV) shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.
4) For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
5) The chemical composition limits shall be in accordance with recognized standards.
6) Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by the Administration.
7) A lower minimum design temperature for quenched and tempered (QT) 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 tests may be omitted subject to agreement with the Administration.

Table 7.4
Pipes (Seamless and Welded) [1], Forgings [2] and Castings [2] for Fuel and Process Piping for Design Temperatures Below 0°C and Down to –165°C [3]
Maximum thickness 25 mm

Minimum design temperature [°C]	Chemical composition [5] and heat treatment	Impact test	
		Test temp. [°C]	Minimum average energy, (KV)
–55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed [6]	See note 4)	27
–65	2.25% nickel steel. Normalized, normalized and tempered or quenched and tempered [6]	–70	34
–90	3.5% nickel steel. Normalized, normalized and tempered or quenched and tempered [6]	–95	34
–165	9% nickel steel [7]. Double normalized and tempered or quenched and tempered.	–196	41
	Austenitic steels, such as grades 304, 304L, 316, 316L, 321 and 347 – solution treated [8]	–196	41
	Aluminium alloys, such as grade 5083 annealed	Not required	
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS			
Sampling frequency			
▪ Each “batch” to be tested			
Toughness (Charpy V-notch test)			
▪ Impact test: Longitudinal test pieces			

Notes:
1) The use of longitudinally or spirally welded pipes shall be specially approved by the Administration.
2) The regulations for forgings and castings may be subject to special consideration by the Administration.
3) The regulations for design temperatures below –165°C shall be specially agreed with the Administration
4) The test temperature shall be 5°C below design temperature or –20°C whichever is lower.
5) The chemical composition limits shall be in accordance with Recognized Standards.
6) A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.
7) This chemical composition is not suitable for castings.
8) Impact tests may be omitted subject to agreement with the Administration.

Table 7.5
Plates and Sections for Hull Structures Required by 6.4.13.1.1.2

Minimum design temperature of hull structure [°C]	Maximum thickness for steel grades [mm]							
	A	B	D	E	AH	DH	EH	FH
0 and above	Recognized Standards							
down to –5	15	25	30	50	25	45	50	50
down to –10	x	20	25	50	20	40	50	50
down to –20	x	x	20	50	x	30	50	50
down to –30	x	x	x	40	x	20	40	50
Below –30	In accordance with Table 7.2 except that the thickness limitation given in Table 7.2 and in footnote 2 of that table does not apply							

Notes:
x – means steel grade not to be used.

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

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

7.4.1.4 Where required the outer pipe or duct containing high pressure gas in the inner pipe shall as minimum fulfil the material requirements for pipe materials with design temperature down to –55°C in table 7.4. (IGF Code, 7.4.1.4)

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

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8 BUNKERING (IGF Code, 8)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 8 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 8.3.1)

8.1 Goal

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. (IGF Code, 8.1)

Guidance on LNG bunkering – see Publication 116/P.

8.2 Functional requirements (IGF Code, 8.2)

8.2.1 This Chapter relates to functional requirements in 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply: (IGF Code, 8.2.1)

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. (IGF Code, 8.2.1.1)

8.2.1.2 For LPG, the following additional requirements apply:

.1 Bunkering systems should be suitable for temperature, pressure and all compositions of LPG used on board . (MSC.1/Circ.1666, 8.2.3)

.2 Means should be provided to manage vapour generated in the tank during bunker transfer. Where means of vapour managements are not provided on ship, vapour return connection should be fitted at bunkering manifold. (MSC.1/Circ.1666, 8.2.4)

8.3 Bunkering station (IGF Code, 8.3)

8.3.1 General (IGF Code, 8.3.1)

8.3.1.1 The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment (see 4.2). (IGF Code, 8.3.1.1)

IACS and IMO interpretation:

The special consideration shall as a minimum include, but not be restricted to, the following design features:

- *segregation towards other areas on the ship*
- *hazardous area plans for the ship*
- *requirements for forced ventilation*
- *requirements for leakage detection (e.g. gas detection and low temperature detection)*
- *safety actions related to leakage detection (e.g. gas detection and low temperature detection)*
- *access to bunkering station from non-hazardous areas through airlocks*
- *monitoring of bunkering station by direct line of sight or by CCTV. (IACS UI GF9 and MSC.1/Circ.1558)*

8.3.1.2 Connections and piping shall be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge. (IGF Code, 8.3.1.2)

8.3.1.3 Arrangements shall be made for safe management of any spilled fuel. (IGF Code, 8.3.1.3)

8.3.1.4 Suitable means shall be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines. Liquid is to be discharged to the liquefied gas fuel tanks or other suitable location. (IGF Code, 8.3.1.4)

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

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

For ships using LPG as fuel, 8.3.1.6 (of the IGF Code) is not applicable. (MSC.1/Circ.1666, 8.3.2)

8.3.1.7 For ships using LPG as fuel, in addition to 8.3.1 (of the IGF Code), bunkering manifolds should be continuously monitored by the ship's crew from a safe area in direct line of sight of the manifold or by CCTV during bunker transfer. (MSC.1/Circ.1666, 15.3.3)

8.3.2 Ships' fuel hoses (IGF Code, 8.3.2)

8.3.2.1 Liquid and vapour hoses used for fuel transfer shall be compatible with the fuel and suitable for the fuel temperature. (IGF Code, 8.3.2.1)

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. (IGF Code, 8.3.2.2)

8.4 Manifold (IGF Code, 8.4)

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. (IGF Code, 8.4.1)

8.5 Bunkering system (IGF Code, 8.5)

8.5.1 An arrangement for purging fuel bunkering lines with inert gas shall be provided. (IGF Code, 8.5.1)

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

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

8.5.4 Means shall be provided for draining any fuel from the bunkering pipes upon completion of operation. (IGF Code, 8.5.4)

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

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

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

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

9 FUEL SUPPLY TO CONSUMERS (IGF Code, 9)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 9 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 9.3.1)

9.1 Goal

The goal of this Chapter is to ensure safe and reliable distribution of fuel to the consumers. (IGF Code, 9.1)

9.2 Functional requirements

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

.1 the fuel supply system shall be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;

.2 the piping system for fuel transfer to the consumers shall be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

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IMO interpretation:

To comply with part A-1, paragraphs 9.2.2, 9.6.1 and 7.3.6.3 of the IGF Code, two independent safety barriers should be in place, while, as far as practicable, using a minimum of flange connections. There should be, no single common flange or other component where one single failure itself may overcome both primary and secondary barriers and may result in a gas leak into the surrounding area causing danger to the persons on board, the environment or the ship.

A single common flange (with two sealing systems) may be accepted at the fuel connection to the gas consumers including GCUs, boilers and components on the engine, such as gas regulating units. (MSC.1/Circ.1670)

.3 fuel lines outside the machinery spaces shall be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage. (IGF Code, 9.2)

For LPG, the following additional requirements apply:

.1 fuel supply systems should be able to supply fuel at the required pressure, temperature and flow rate; and (MSC.1/Circ.1666, 9.2.4)

.2 where fuel supply systems supply LPG in the liquid state, purging, drain, vent and leakage should be subject to special consideration to provide an equivalent level of safety of fuel in the gas state. (MSC.1/Circ.1666, 9.2.5)

9.3 Redundancy of fuel supply (IGF Code, 9.3)

9.3.1 For single fuel installations the fuel supply system shall be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power. (IGF Code, 9.3.1)

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

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. (IGF Code, 9.3.3)

9.4 Safety functions of gas supply system (IGF Code, 9.4)

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

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

9.4.2 The main gas supply line to each gas consumer or set of consumers shall be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers, and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve shall automatically cut off the gas supply when activated by the safety system required in 15.2.2. (IGF Code, 9.4.2)

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

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

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

.2 the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened. (IGF Code, 9.4.4)

Notwithstanding 9.4.4 (of the IGF Code), where fuel supply systems supply LPG in the liquid state, relevant bleed lines should be led to the fuel tank or gas-liquid separator or similar device to prevent LPG liquid from being released to the atmosphere. (MSC.1/Circ.1666, 9.3.2)

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

9.4.6 The double block and bleed valves shall also be used for normal stop of the engine. (IGF Code, 9.4.6)

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

In addition to 9.4.7 (of the IGF Code), where fuel supply systems supply LPG in the liquid state, vent lines should be led to the fuel tank or gas-liquid separator or similar device. (MSC.1/Circ.1666, 9.3.3)

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. (IGF Code, 9.4.8)

9.4.9 For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined. (IGF Code, 9.4.9)

9.4.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations means shall be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected a valve shall be automatically shut off*. 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. (not applicable to LPG). (IGF Code, 9.4.10)

The provision of 9.4.10 (of the IGF Code) does not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 9.3.4)

* The shutdown should be time delayed to prevent shutdown due to transient load variations.

9.5 Fuel distribution outside of machinery space (IGF Code, 9.5)

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

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

9.5.3 The requirements in 9.5.4 to 9.5.6 shall apply to ships constructed on or after 1 January 2024 in lieu of the requirements in 9.5.1 and 9.5.2. (IGF Code, 9.5.3)

9.5.4 Where gaseous fuel pipes pass through enclosed spaces in the ship, they shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in15.8 shall be provided. Other solutions providing an equivalent safety level may also be accepted by the Administration. (IGF Code, 9.5.4)

9.5.5 The requirement in 9.5.4 need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces. (IGF Code, 9.5.5)

9.5.6 Liquefied fuel pipes shall be protected by a secondary enclosure able to contain leakages. If the piping system is in a fuel preparation room or a tank connection space, the Administration may waive this requirement. Where gas detection as required in 15.8.1.2 is not fit for purpose, the secondary enclosures around liquefied fuel pipes shall be provided with leakage detection by means of pressure or temperature monitoring systems, or any combination thereof. The secondary enclosure shall be able to withstand the maximum pressure that may build up in the enclosure in case of leakage from the fuel piping. For this purpose, the secondary enclosure may need to be arranged with a pressure relief system that prevents the enclosure from being subjected to pressures above their design pressures. (IGF Code, 9.5.6)

9.6 Fuel supply to consumers in gas-safe machinery spaces (IGF Code, 9.6)

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

.1 the gas piping shall be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms shall be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system shall be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

.2 the gas fuel piping shall be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct shall be equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors shall comply with the required explosion protection in the installation area. The ventilation outlet shall be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited; or

.3 other solutions providing an equivalent safety level may also be accepted by the Administration. (IGF Code, 9.6.1)

Note:
See also interpretation in 9.2.2.

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*. (IGF Code, 9.6.1)

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

9.7 Gas fuel supply to consumers in ESD-protected machinery spaces (IGF Code, 9.7)

Note:
The provision of 9.7 (of the IGF Code) does not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 9.3.5)

9.7.1 The pressure in the gas fuel supply system shall not exceed 1.0 MPa. (IGF Code, 9.7.1)

9.7.2 The gas fuel supply lines shall have a design pressure not less than 1.0 MPa. (IGF Code, 9.7.2)

9.8 Design of ventilated duct, outer pipe against inner pipe gas leakage (IGF Code, 9.8)

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

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

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

.2 local instantaneous peak pressure in way of the rupture: this pressure shall be taken as the critical pressure given by the following expression:

$$p = p_0 \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where:
P_0 = maximum working pressure of the inner pipe
k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat
k = 1.31 for CH_4.

The tangential membrane stress of a straight pipe shall not exceed the tensile strength divided by 1.5 ($R_m/1.5$) when subjected to the above pressures. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports shall then be submitted. (IGF Code, 9.8.2)

For LPG, the most conservative value of k should be selected for considering expected composition of fuel (propane: 1.13, butane: 1.096). (MSC.1/Circ.1666, 9.3.6)

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

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

9.9 Compressors and pumps (IGF Code, 9.9)

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. (IGF Code, 9.9.1)

9.9.2 Compressors and pumps shall be suitable for their intended purpose. All equipment and machinery shall be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would include, but not be limited to:

.1 environmental;
.2 shipboard vibrations and accelerations;
.3 effects of pitch, heave and roll motions, etc.; and
.4 gas composition. (IGF Code, 9.9.2)

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. (IGF Code, 9.9.3)

9.9.4 Compressors and pumps shall be fitted with accessories and instrumentation necessary for efficient and reliable function. (IGF Code, 9.9.4)

10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS (IGF CODE, 10)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 10 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 10.3.1)

10.1 Goal

The goal of this Chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy. (IGF Code, 10.1)

10.2 Functional requirements

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

.1 the exhaust systems shall be configured to prevent any accumulation of un-burnt gaseous fuel;

.2 unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture shall be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

.3 the explosion venting shall be led away from where personnel may normally be present; and

.4 all gas consumers shall have a separate exhaust system. (IGF Code, 10.2)

For LPG, the following additional requirements apply:

.5 fuel consumers should be suitably designed for operation with possible compositions of LPG fuel. (MSC.1/Circ.1666, 10.2)

10.3 Internal combustion engines of piston type (IGF Code, 10.3)

10.3.1 General (IGF Code, 10.3.1)

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. (IGF Code, 10.3.1.1)

10.3.1.1.1 For ships constructed on or after 1 January 2024, the exhaust system shall be equipped with explosion relief systems unless designed to accommodate the worst case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation of the potential for unburnt gas in the exhaust system is to be undertaken covering the complete system from the cylinders up to the open end. This detailed evaluation shall be reflected in the safety concept of the engine. (IGF Code, 10.3.1.1.1)

10.3.1.2 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase shall be carried out and reflected in the safety concept of the engine. (IGF Code, 10.3.1.2)

10.3.1.3 Each engine other than two-stroke crosshead diesel engines shall be fitted with vent systems independent of other engines for crankcases and sumps. (IGF Code, 10.3.1.3)

10.3.1.4 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media shall be vented to a safe location in the atmosphere. (IGF Code, 10.3.1.4)

10.3.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit shall be verified. (IGF Code, 10.3.1.5)

10.3.1.6 A means shall be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations. (IGF Code, 10.3.1.6)

10.3.1.7 For engines starting on fuels covered by this *Publication* (Code), if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve shall be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system shall be provided. (IGF Code, 10.3.1.7)

10.3.1.8 Notwithstanding 10.3.1.7, for ships using LPG as fuel and with engines starting on fuels other than those covered by this *Publication*, 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 should be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system should be provided. (MSC.1/Circ.1666, 10.3.4)

10.3.2 Dual fuel engines (IGF Code, 10.3.2)

10.3.2.1 In case of shutoff of the gas fuel supply, the engines shall be capable of continuous operation by oil fuel only without interruption. (IGF Code, 10.3.2.1)

10.3.2.2 An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation and vice versa with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine shall automatically change to oil fuel mode. Manual activation of gas system shutdown shall always be possible. (IGF Code, 10.3.2.2)

10.3.2.3 In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine. (IGF Code, 10.3.2.3)

10.3.3 Gas-only engines

In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine. (IGF Code, 10.3.3)

10.3.4 Multi-fuel engines (IGF Code, 10.3.4)

10.3.4.1 In case of shutoff of one fuel supply, the engines shall be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power. (IGF Code, 10.3.4.1)

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. (IGF Code, 10.3.4.2)

	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 Main and auxiliary boilers (IGF Code, 10.4)

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. (IGF Code, 10.4.1)

10.4.2 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel. (IGF Code, 10.4.2)

10.4.3 Burners shall be designed to maintain stable combustion under all firing conditions. (IGF Code, 10.4.3)

10.4.4 On main/propulsion boilers an automatic system shall be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing. (IGF Code, 10.4.4)

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. (IGF Code, 10.4.5)

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. (IGF Code, 10.4.6)

10.4.7 On the fuel pipe of each gas burner a manually operated shutoff valve shall be fitted. (IGF Code, 10.4.7)

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. (IGF Code, 10.4.8)

10.4.9 The automatic fuel changeover system required by 10.4.4 shall be monitored with alarms to ensure continuous availability. (IGF Code, 10.4.9)

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. (IGF Code, 10.4.10)

10.4.11 Arrangements shall be made to enable the boilers purging sequence to be manually activated. (IGF Code, 10.4.11)

10.5 Gas turbines (IGF Code, 10.5)

10.5.1 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a safe location, away from personnel. (IGF Code, 10.5.1)

10.5.2 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 5.6 and 9.7, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure. (IGF Code, 10.5.2)

Notwithstanding 10.5.2 of this *Publication* (the IGF Code) for ships using LPG as fuel, the gas turbine should be fitted in a gas-tight enclosure arranged in accordance with 10.5.3. Gas leakage in the gas-tight enclosure and the consequence should be evaluated based on the risk assessment in accordance with 4.2 and to the satisfaction of the Administration. (MSC.1/Circ.1666, 10.3.2)

10.5.3 Gas detection systems and shutdown functions shall be as outlined for ESD protected machinery spaces. (IGF Code, 10.5.3)

10.5.4 Ventilation for the enclosure shall be as outlined in Chapter 13 for ESD protected machinery spaces, but shall in addition be arranged with full redundancy (2 × 100% capacity fans from different electrical circuits). (IGF Code, 10.5.4)

10.5.5 For other than single fuel gas turbines, an automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum fluctuation of the engine power. (IGF Code, 10.5.5)

10.5.6 Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply shall be shutdown. (IGF Code, 10.5.6)

10.5.7 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures. (IGF Code, 10.5.7)

11 FIRE SAFETY (IGF CODE, 11)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 11 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 11.3.1)

11.1 Goal

The goal of this Chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of natural gas as ship fuel. (IGF Code, 11.1)

11.2 Functional requirements

This Chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17. (IGF Code, 11.2)

11.3 Fire protection (IGF Code, 11.3)

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. (IGF Code, 11.3.1)

IACS interpretation:

1. *Fire protection in 11.3.1 means structural fire protection, not including means of escape.*
2. *Notwithstanding interpretation 1, any enclosed spaces containing equipment for fuel preparation such as pumps or compressors or other potential ignition sources are to comply with regulation 11.8 of the IGF Code as amended by Resolution MSC.475(102). (IACS UI GF13)*

For LPG, additionally, the fuel preparation room should be separated from a machinery space of category A and rooms with high fire risks. The separation is to be done by a cofferdam of at least 900 mm with insulation of "A-60" class. (MSC.1/Circ.1666, 11.3.2)

11.3.2 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, shall be shielded by "A-60" class divisions. The "A-60" class divisions shall extend up to the underside of the deck of the navigation bridge. In addition, fuel tanks shall be segregated from cargo in accordance with the requirements of *the International Maritime Dangerous Goods (IMDG) Code* where the fuel tanks are regarded as bulk packaging. For the purposes of the stowage and segregation requirements of the IMDG Code, a fuel tank on the open deck shall be considered a class 2.1 package. (IGF Code, 11.3.2)

11.3.3 The space containing fuel containment system shall be separated from the machinery spaces of category A or other rooms with high fire risks*. The separation shall be done by a cofferdam of at least 900 mm with insulation of "A-60" class. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system shall be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. For type C tanks, the fuel storage hold space may be considered as a cofferdam. (IGF Code, 11.3.3)

IACS and IMO interpretation:

The following "other rooms with high fire risk" should as a minimum be considered, but not be restricted to:

1. *cargo spaces except cargo tanks for liquids with flashpoint above 60°C and except cargo spaces exempted in accordance with SOLAS regulations II-2/10.7.1.2 or II-2/10.7.1.4;*
2. *vehicle, ro-ro and special category spaces;*

3. *service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m² or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery space, as provided in SOLAS regulations II-2/9.2.2.4, II-2/9.2.3.3 and II-2/9.2.4; and*

4. *accommodation spaces of greater fire risk: saunas, sale shops, barber shops and beauty parlours and public spaces containing furniture and furnishing of other than restricted fire risk and having deck area of 50 m² or more, as provided in SOLAS regulation II-2/9.2.2.3. (IACS UI GF17 and MSC.1/Circ.1591)*

11.3.3.1 Notwithstanding the last sentence in 11.3.3, for ships constructed on or after 1 January 2024, the fuel storage hold space may be considered as a cofferdam provided that:

.1 the type C tank is not located directly above machinery spaces of category A or other rooms with high fire risk; and

.2 the minimum distance to the "A-60" boundary from the outer shell of the type C tank or the boundary of the tank connection space, if any, is not less than 900 mm. (IGF Code, 11.3.3.1)

11.3.4 The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk. (IGF Code, 11.3.4)

11.3.5 The fire protection of fuel pipes led through ro-ro spaces shall be subject to special consideration by the Administration depending on the use and expected pressure in the pipes. (IGF Code, 11.3.5)

11.3.6 The bunkering station shall be separated by "A-60" class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class "A-0". (IGF Code, 11.3.6)

11.3.7 If an ESD protected machinery spaces is separated by a single boundary, the boundary shall be of "A-60" class division. (IGF Code, 11.3.7)

11.4 Fire main (IGF Code, 11.4)

11.4.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system simultaneously. (IGF Code, 11.4.1)

11.4.2 When the fuel storage tank(s) is located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section from the supply of water. (IGF Code, 11.4.2)

11.5 Water spray system (IGF Code, 11.5)

11.5.1 A water spray system shall be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck. (IGF Code, 11.5.1)

11.5.2 The water spray system shall also provide coverage for boundaries of the superstructures, compressor rooms, pump-rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks unless the tank is located 10 meters or more from the boundaries. (IGF Code, 11.5.2)

11.5.3 The system shall be designed to cover all areas as specified above with an application rate of 10 *l*/min/m² for the largest horizontal projected surfaces and 4 *l*/min/m² for vertical surfaces. (IGF Code, 11.5.3)

11.5.4 Stop valves shall be fitted in the water spray application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected. (IGF Code, 11.5.4)

11.5.5 The capacity of the water spray pump shall be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected. (IGF Code, 11.5.5)

11.5.6 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve shall be provided. (IGF Code, 11.5.6)

11.5.7 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system shall be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected. (IGF Code, 11.5.7)

11.5.8 The nozzles shall be of an approved full bore type and they shall be arranged to ensure an effective distribution of water throughout the space being protected. (IGF Code, 11.5.8)

11.6 Dry chemical powder fire-extinguishing system

11.6.1 A permanently installed dry chemical powder fire-extinguishing system shall be installed in the bunkering station area to cover all possible leak points. The capacity shall be at least 3.5 kg/s for a minimum of 45 s. The system shall be arranged for easy manual release from a safe location outside the protected area. (IGF Code, 11.6.1)

11.6.2 In addition to any other portable fire extinguishers that may be required elsewhere in IMO instruments, one portable dry powder extinguisher of at least 5 kg capacity shall be located near the bunkering station. (IGF Code, 11.6.2)

11.7 Fire detection and alarm system (IGF Code, 11.7)

11.7.1 A fixed fire detection and fire alarm system complying with the *Fire Safety Systems Code* shall be provided for the fuel storage hold spaces and the ventilation trunk for fuel containment system below deck, and for all other rooms of the fuel gas system where fire cannot be excluded. (IGF Code, 11.7.1)

11.7.2 Smoke detectors alone shall not be considered sufficient for rapid detection of a fire. (IGF Code, 11.7.2)

11.8 Fuel preparation room fire-extinguishing systems

For ships constructed on or after 1 January 2024, fuel preparation rooms containing pumps, compressors or other potential ignition sources shall be provided with a fixed fire-extinguishing system complying with the provisions of SOLAS regulation II-2/10.4.1.1 and taking into account the necessary concentrations/application rate required for extinguishing gas fires. (IGF Code, 11.8)

For LPG, a fuel preparation room should be provided with a fixed fire-extinguishing system complying with the provisions of the *FSS Code* and taking into account the necessary concentrations/application rate required for extinguishing LPG gas fires. (MSC.1/Circ.1666, 11.3.3)

12 EXPLOSION PREVENTION (IGF CODE, 12)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 12 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 12.3.1)

12.1 Goal

The goal of this Chapter is to provide for the prevention of explosions and for the limitation of effects from explosion. (IGF Code, 12.1)

12.2 Functional requirements

This Chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:

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

.1 reducing number of sources of ignition; and
.2 reducing the probability of formation of ignitable mixtures. (IGF Code, 12.2)

12.3 General

12.3.1 Hazardous areas on open deck and other spaces not addressed in this Chapter shall be decided based on a recognized standard*. The electrical equipment fitted within hazardous areas shall be according to the same standard. (IGF Code, 12.3.1)

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

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*. (IGF Code, 12.3.2)

* Refer to IEC standard 60092-502: IEC 60092-502:1999 *Electrical Installations in Ships – Tankers – Special Features* and IEC 60079-10-1:2008 *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.*

12.3.3 Electrical equipment fitted in an ESD-protected machinery space shall fulfil the following:

.1 in addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans shall be certified safe for hazardous area zone 1; and
.2 all electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 shall be automatically disconnected, if gas concentrations above 40% LEL is detected by two detectors in the space containing gas-fuelled consumers. (IGF Code, 12.3.3)

12.4 Area classification

IMO interpretation:

Functional requirements applied to gas admission valves at dual fuel engines and gas engines:

1. *The risk assessment, in accordance with the relevant standards on area classification as set out in section 12.4, should be understood as a procedure equivalently applicable to the examples for hazardous area zones as laid out in section 12.5 for the categorization of gas admission valves at dual fuel engines and gas engines.*
2. *Section 12.4 should be interpreted as the guiding methodology for the categorization of gas admission valves at dual fuel engines and gas engines. If no additional safety measures and no corresponding risk assessment in accordance with section 12.4 are available, the examples in section 12.5 should apply. (MSC.1/Circ.1605)*

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. (IGF Code, 12.4.1)

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*. See also 12.5 below. (IGF Code, 12.4.2)

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* 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.*

12.4.3 Ventilation ducts shall have the same area classification as the ventilated space. (IGF Code, 12.4.3)

12.4.4 For LPG, the classification of a hazardous area should be subject to special consideration to characteristics of LPG (e.g. density, LEL). IEC 60079-10-1 may be referred, if necessary, to determine hazardous areas. (MSC.1/Circ.1666, 12.3.2)

12.5 Hazardous area zones (IGF Code, 12.5)

Interpretation:
See paragraph 12.4. (MSC.1/Circ.1605)

12.5.1 Hazardous area zone 0

This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel. (IGF Code, 12.5.1)

12.5.2 Hazardous area zone 1*

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

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces* and interbarrier spaces;

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

***** IACS and IMO interpretation:***

1. *For the purposes of hazardous area classification, fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, shall be considered non-hazardous.*
2. *Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they shall be considered hazardous area zone 1.*
3. *Where the fuel storage hold spaces include bolted access to the tank connection space, they shall be considered hazardous area zone 2. (IACS UI GF14 and MSC.1/Circ.1605)*

.2 fuel preparation room arranged with ventilation according to 13.6;

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet*, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

* Such areas are, for example, all areas within 3 m of fuel tank hatches, ullage openings or sounding pipes for fuel tanks located on open deck and gas vapour outlets.

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes, semi-enclosed bunkering stations;

.7 the ESD-protected machinery space is considered a non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1;

.8 a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

.9 except for type C tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather. (IGF Code, 12.5.2)

12.5.3 Hazardous area zone 2*

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

12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1. (IGF Code, 12.5.3.1)

12.5.3.2 Space containing bolted hatch to tank connection space. (IGF Code, 12.5.3.2)

13 VENTILATION (IGF CODE, 13)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 13 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 13.3.1)

13.1 Goal

The goal of this Chapter is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment. (IGF Code, 13.1)

13.2 Functional requirements

This Chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

For LPG, in particular, the capacity and layout of ventilation system should be so designed that efficiency of ventilation is ensured considering the density of LPG gas. (the gas is heavier than air) (MSC.1/Circ.1666, 13.2)

13.3 General (IGF Code, 13)

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. (IGF Code, 13.3.1)

13.3.2 Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served. (IGF Code, 13.3.2)

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

.1 Ventilation fans shall not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, shall be of non-sparking construction defined as:

- **.1** impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;
- **.2** impellers and housings of non-ferrous metals;
- **.3** impellers and housings of austenitic stainless steel;
- **.4** impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or
- **.5** any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

.2 In no case shall the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places. (IGF Code, 13.3.3)

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 *Publication* (Code). (IGF Code, 13.3.4)

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. (IGF Code, 13.3.5)

For LPG, additionally, air outlets and air inlets for hazardous enclosed spaces should be arranged to prevent exhausted gas from re-entering the space through air inlets, based on the risk assessment in accordance with 4.2 and to the satisfaction of the Administration. (MSC.1/Circ.1666, 13.3.2)

13.3.6 Air outlets from non-hazardous spaces shall be located outside hazardous areas. (IGF Code, 13.3.6)

13.3.7 Air outlets from hazardous enclosed spaces shall be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space. (IGF Code, 13.3.7)

13.3.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form. (IGF Code, 13.3.8)

For LPG, additionally, when determining the required ventilation capacity, special consideration should be given to the density and lower explosion limit (LEL) of LPG gas, which should be supported by numerical calculations such as CFD analysis. (MSC.1/Circ.1666, 13.3.3)

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

- **.1** During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it shall be required to:
  - **.1** proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and
  - **.2** pressurize the space.
- **.2** Operation of the overpressure ventilation shall be monitored and in the event of failure of the overpressure ventilation:
  - **.1** an audible and visual alarm shall be given at a manned location; and
  - **.2** if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard* shall be required. (IGF Code, 13.3.9)

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

13.3.10 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an airlock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space shall be monitored and in the event of failure of the extraction ventilation:

.1 an audible and visual alarm shall be given at a manned location; and
.2 if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space shall be required. (IGF Code, 13.3.10)

13.3.11 For LPG, the number and location of the extraction points of the ventilation in each space should be considered taking into account the size and layout of the space. Where bottom arrangements are complicated, it should be demonstrated based on ventilation analysis that capacity and duct arrangements of ventilation are adequate for the space. (MSC.1/Circ.1666, 13.3.5)

Considering the physical properties of the gaseous form of LPG, which is heavier than air, the ends of the exhaust ducts should be located in the lower part of the room, possibly close to the bottom of the room.

13.4 Ventilation of tank connection space (IGF Code, 13.4)

13.4.1 The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment (see 4.2). (IGF Code, 13.4.1)

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

For LPG, approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for the tank connection space, fuel preparation room or any other space as deemed necessary by a risk assessment in accordance with 4.2 and to the satisfaction of the Administration. (MSC.1/Circ.1666, 13.3.4)

13.5 Ventilation of machinery spaces (IGF Code, 13.5)

13.5.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems. (IGF Code, 13.5.1)

IACS and IMO interpretation:

Spaces enclosed in the boundaries of machinery spaces (such as purifier's room, engine room workshops and stores) are considered an integral part of machinery spaces containing gas-fuelled consumers and, therefore, their ventilation system does not need to be independent of the one of machinery spaces. (IACS UI GF10 and MSC.1/Circ.1558)

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. (IGF Code, 13.5.2)

The provisions in 13.5.2, (… of the IGF Code) do not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 13.3.6)

13.5.3 For ESD protected machinery spaces the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard acceptable to the Organization (IMO)*. (IGF Code, 13.5.3)

The provisions in (...) 13.5.3, (... of the IGF Code) do not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 13.3.6)

* Refer to IEC 60079-10-1.

13.5.4 The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms shall be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable. (IGF Code, 13.5.4)

The provisions in (...) 13.5.4 (of the IGF Code) do not apply to ships using LPG as fuel. (MSC.1/Circ.1666, 13.3.6)

13.6 Ventilation of fuel preparation room (IGF Code, 13.6)

13.6.1 Fuel preparation rooms, shall be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour. (IGF Code, 13.6.1)

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. (IGF Code, 13.6.2)

13.6.3 Ventilation systems for fuel preparation rooms, shall be in operation when pumps or compressors are working. (IGF Code, 13.6.3)

13.7 Ventilation of bunkering station

Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1. (IGF Code, 13.7)

13.8 Ventilation of ducts and double pipes (IGF Code, 13.8)

13.8.1 Ducts and double pipes containing fuel piping shall be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not applicable to double pipes in the engine-room if fulfilling 9.6.1.1. (IGF Code, 13.8.1)

13.8.2 The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms shall be independent of all other ventilation systems. (IGF Code, 13.8.2)

IACS and IMO interpretation:

Double piping and gas valve unit spaces in gas safe engine-rooms are considered an integral part of the fuel supply systems and, therefore, their ventilation system does not need to be independent of other fuel supply ventilation systems provided such fuel supply systems contain only gaseous fuel. (IACS UI GF11 and MSC.1/Circ.1558)

13.8.3 The ventilation inlet for the double wall piping or duct shall always be located in a non-hazardous area away from ignition sources. The inlet opening shall be fitted with a suitable wire mesh guard and protected from ingress of water. (IGF Code, 13.8.3)

IACS and IMO interpretation:

The ventilation inlet for the double wall piping or duct shall always be located in a non-hazardous area in open air away from ignition sources. (IACS UI GF12 and MSC.1/Circ.1558)

13.8.4 The capacity of the ventilation for a pipe duct or double wall piping may be below 30 air changes per hour if a flow velocity of minimum 3 m/s is ensured. The flow velocity shall be calculated for the duct with fuel pipes and other components installed. (IGF Code, 13.8.4)

14 ELECTRICAL INSTALLATIONS (IGF CODE, 14)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 14 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 14.3.1)

14.1 Goal

The goal of this Chapter is to provide for electrical installations that minimizes the risk of ignition in the presence of a flammable atmosphere. (IGF Code, 14.1)

14.2 Functional requirements

This Chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits. (IGF Code, 14.2)

14.3 General

14.3.1 Electrical installations shall be in compliance with a standard at least equivalent to those acceptable to the Organization (IMO)*. (IGF Code, 14.3.1)

* Refer to IEC 60092 series standards, as applicable.

14.3.2 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement. (IGF Code, 14.3.2)

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 (IMO)*. (IGF Code, 14.3.3)

* Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.

Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.

For LPG, additionally, equipment for hazardous areas should be of a certified safe type appropriate for compositions of LPG in accordance with IEC 60079-20.

IEC 60079-20 classifies the temperature class and equipment groups for propane and butane as the following:

	Temperature class	Equipment group
Propane	T2	IIA
Butane	T2	IIA

Equipment should be certified to IEC temperature class T2 and equipment group IIA. (MSC.1/Circ.1666, 14.3.2)

14.3.4 Failure modes and effects of single failure for electrical generation and distribution systems in 14.2 shall be analysed and documented to be at least equivalent to those acceptable to the Organization (IMO)*. (IGF Code, 14.3.4)

* Refer to IEC 60812.

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. (IGF Code, 14.3.5)

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. (IGF Code, 14.3.6)

14.3.7 Arrangements shall be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre. (IGF Code, 14.3.7)

14.3.8 Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations. (IGF Code, 14.3.8)

14.3.9 For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type shall be de-energized upon loss of overpressure in the space. (IGF Code, 14.3.9)

14.3.10 Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, shall be of a certified safe type. (IGF Code, 14.3.10)

15 CONTROL, MONITORING AND SAFETY SYSTEMS (IGF CODE, 15)

Note:
Unless expressly provided otherwise, the requirements of (IGF Code part A-1) Chapter 15 apply to ships using LPG as fuel. (MSC.1/Circ.1666, 15.3.1)

15.1 Goal

The goal of this Chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other chapters of this *Publication* (Code). (IGF Code, 15.1)

15.2 Functional requirements

This Chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

.1 the control, monitoring and safety systems of the gas-fuelled installation shall be so arranged that the remaining power for propulsion and power generation is in accordance with 9.3.1 in the event of single failure;

.2 a gas safety system shall be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention;

.3 for ESD protected machinery configurations the safety system shall shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

.4 the safety functions shall be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

.5 the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

.6 where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent gas control and gas safety systems. (IGF Code, 15.1)

15.3 General (IGF Code, 15.3)

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. (IGF Code, 15.3.1)

15.3.2 A bilge well in each tank connection space of an independent liquefied gas storage tank shall be provided with both a level indicator* and a temperature sensor. Alarm shall be given at high level in the bilge well. Low temperature indication shall activate the safety system. (IGF Code, 15.3.2)

IACS and IMO interpretation:

The "level indicator" required by 15.3.2 (of the IGF Code) is understood to be required for the purposes of indicating an alarm status only; a level switch (float switch) is an instrument example considered to meet this requirement. (IACS UI GF18 and MSC.1/Circ.1591)

15.3.3 For tanks not permanently installed in the ship a monitoring system shall be provided as for permanently installed tanks. (IGF Code, 15.3.3)

15.4 Bunkering and liquefied gas fuel tank monitoring (IGF Code, 15.4)

15.4.1 Level indicators for liquefied gas fuel tanks

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

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

.3 Liquefied gas fuel tank liquid level gauges may be of the following types:

- **.1** indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or
- **.2** closed devices, which do not penetrate the liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices. (IGF Code, 15.4.1)

15.4.2 Tank overflow control

.1 Each liquefied gas fuel tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the liquefied gas fuel tank from becoming liquid full.

.3 The position of the sensors in the liquefied gas fuel tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking*, testing of high level alarms shall be conducted by raising the fuel liquid level in the liquefied gas fuel tank to the alarm point.

IACS and IMO interpretation:

** The expression "each dry-docking" refers to:*

1. *for cargo ships, the survey of the outside of the ship's bottom required for the renewal of the Cargo Ship Safety Construction Certificate and/or the Cargo Ship Safety Certificate; and*
2. *for passenger ships, the survey of the outside of the ship's bottom to be carried out according to paragraphs 5.10.1 and 5.10.2 of the Survey Guidelines under the Harmonized System of Survey and Certification, (HSSC), 2017 (resolution A.1121(30), as may be amended). (IACS UI GF1, MSC.1/Circ.1591)*

.4 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to fuel operation in accordance with 18.4.3 of *IGF Code*.

.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. (IGF Code, 15.4.2)

15.4.3 The vapour space of each liquefied gas fuel tank shall be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control station or onboard safety centre. (IGF Code, 15.4.3)

15.4.4 The pressure indicators shall be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank. (IGF Code, 15.4.4)

15.4.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms shall be activated before the set pressures of the safety valves are reached. (IGF Code, 15.4.5)

15.4.6 Each fuel pump discharge line and each liquid and vapour fuel manifold shall be provided with at least one local pressure indicator. (IGF Code, 15.4.6)

15.4.7 Local-reading manifold pressure indicator shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore. (IGF Code, 15.4.7)

15.4.8 Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indicator. (IGF Code, 15.4.8)

15.4.9 At least one of the pressure indicators provided shall be capable of indicating throughout the operating pressure range. (IGF Code, 15.4.9)

15.4.10 For submerged fuel-pump motors and their supply cables, arrangements shall be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre. (IGF Code, 15.4.10)

15.4.11 Except for independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank shall be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level. (IGF Code, 15.4.11)

15.5 Bunkering control (IGF Code, 15.5)

15.5.1 Control of the bunkering shall be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by 15.4.11, and tank level shall be monitored. Remotely controlled valves required by 8.5.3 and 11.5.7 shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location. (IGF Code, 15.5.1)

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. (IGF Code, 15.5.2)

15.5.3 If gas is detected in the ducting around the bunkering lines an, audible and visual alarm and emergency shutdown shall be provided at the bunkering control location. (IGF Code, 15.5.3)

15.6 Gas compressor monitoring (IGF Code, 15.6)

15.6.1 Gas compressors shall be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms shall include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation. (IGF Code, 15.6.1)

15.6.2 Temperature monitoring for the bulkhead shaft glands and bearings shall be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station. (IGF Code, 15.6.2)

15.7 Gas engine monitoring

In addition to the instrumentation provided in accordance with part C of SOLAS, Chapter II-1, indicators shall be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

.1 operation of the engine in case of gas-only engines; or
.2 operation and mode of operation of the engine in the case of dual fuel engines. (IGF Code, 15.7)

15.8 Gas detection (IGF Code, 15.8)

15.8.1 Permanently installed gas detectors shall be fitted in:

.1 the tank connection spaces;
.2 all ducts around fuel pipes;
.3 machinery spaces containing gas piping, gas equipment or gas consumers;
.4 compressor rooms and fuel preparation rooms;
.5 other enclosed spaces containing fuel piping or other fuel equipment without ducting;
.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;
.7 airlocks;
.8 gas heating circuit expansion tanks;
.9 motor rooms associated with the fuel systems; and
.10 or at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2. (IGF Code, 15.8.1)

For LPG, additionally, permanently installed gas detectors should be fitted at ventilation inlets of accommodation and machinery spaces and other rooms with high fire risk*, unless Administration deems it unnecessary based on a risk assessment in accordance with 4.2, as well as at the bunkering station as required in Chapter 8 of this *Publication* (these *Interim Guidelines*). (MSC.1/Circ.1666, 15.3.2)

IACS and IMO interpretation:

The following "other rooms with high fire risk" should as a minimum be considered, but not be restricted to:

1. *cargo spaces except cargo tanks for liquids with flashpoint above 60°C and except cargo spaces exempted in accordance with SOLAS regulations II-2/10.7.1.2 or II-2/10.7.1.4;*
2. *vehicle, ro-ro and special category spaces;*
3. *service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m² or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery space, as provided in SOLAS regulations II-2/9.2.2.4, II-2/9.2.3.3 and II-2/9.2.4; and*
4. *accommodation spaces of greater fire risk: saunas, sale shops, barber shops and beauty parlours and public spaces containing furniture and furnishing of other than restricted fire risk and having deck area of 50 m2 or more, as provided in SOLAS regulation II-2/9.2.2.3. (IACS UI GF17 and MSC.1/Circ.1591)*

15.8.2 In each ESD-protected machinery space, redundant gas detection systems shall be provided. (IGF Code, 15.8.2)

15.8.3 The number of detectors in each space shall be considered taking into account the size, layout and ventilation of the space. (IGF Code, 15.8.3)

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. (IGF Code, 15.8.4)

15.8.5 Gas detection equipment shall be designed, installed and tested in accordance with a recognized standard*. (IGF Code, 15.8.5)

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

15.8.6 An audible and visible alarm shall be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system shall be activated at 40% of LEL at two detectors (see footnote 1 in table 1). (IGF Code, 15.8.6)

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). (IGF Code, 15.8.7)

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. (IGF Code, 15.8.8)

15.8.9 Gas detection required by this section shall be continuous without delay. (IGF Code, 15.8.9)

15.9 Fire detection

Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in table 1 below. (IGF Code, 15.9)

15.10 Ventilation (IGF Code, 15.10)

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. (IGF Code, 15.10.1)

IACS and IMO interpretation:

Acceptable means to confirm that the ventilation system has the "required ventilating capacity" in operation are, but not limited to:

1. *monitoring of the ventilation electric motor or fan operation combined with underpressure indication; or*
2. *monitoring of the ventilation electric motor or fan operation combined with ventilation flow indication ; or*
3. *monitoring of ventilation flow rate to indicate that the required air flow rate is established. (IACS UI GF15 and MSC.1/Circ.1605)*

15.10.2 For ESD protected machinery spaces the safety system shall be activated upon loss of ventilation in engine-room. (IGF Code, 15.10.2)

15.11 Safety functions of fuel supply systems (IGF Code, 15.11)

15.11.1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply shall not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect shall be placed at the operating station for the shutoff valves in the fuel supply lines. (IGF Code, 15.11.1)

15.11.2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply shall not be operated until the leak has been found and dealt with. Instructions to this effect shall be placed in a prominent position in the machinery space. (IGF Code, 15.11.2)

15.11.3 A caution placard or signboard shall be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, shall not be done when the engine(s) is running on gas. (IGF Code, 15.11.3)

15.11.4 Compressors, pumps and fuel supply shall be arranged for manual remote emergency stop from the following locations as applicable:

.1 navigation bridge;
.2 cargo control room;
.3 onboard safety centre;
.4 engine control room;
.5 fire control station; and
.6 adjacent to the exit of fuel preparation rooms.

The gas compressor shall also be arranged for manual local emergency stop. (IGF Code, 15.11.4)

Table 1:
Monitoring of gas supply system to engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
1. Gas detection in tank connection space at 20% LEL	X			
2. Gas detection on two detectors[1)] in tank connection space at 40% LEL	X	X		
3. Fire detection in fuel storage hold space	X			
4. Fire detection in ventilation trunk for fuel containment system below deck	X			
5. Bilge well high level in tank connection space	X			
6. Bilge well low temperature in tank connection space	X	X		
7. Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			
8. Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X[2)]		
9. Gas detection in fuel preparation room at 20% LEL	X			
10. Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X[2)]		

Parameter	Alarm	Automatic shutdown of tank valve[6]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
11. 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
12. 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
13. Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	X			
14. Gas detection on two detectors[1] in ESD protected machinery space containing gas-fuelled engines at 40% LEL	X		X	It shall also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
15. Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X[2]	
16. Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5]	X		X[3]	If double pipe fitted in machinery space containing gas-fuelled engines
17. Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	X		X	
18. Fire detection in machinery space containing gas-fuelled engines	X			
19. Abnormal gas pressure in gas supply pipe	X			
20. Failure of valve control actuating medium	X		X[4]	Time delayed as found necessary
21. Automatic shutdown of engine (engine failure)	X		X[4]	
22. Manually activated emergency shutdown of engine	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.

2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.

3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.

4) Only double block and bleed valves to close.

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
[5)] If the duct is protected by inert gas (see 9.6.1.1) then loss of inert gas overpressure shall lead to the same actions as given in this table. [6)] Valves referred to in 9.4.1.				

16 MANUFACTURE, WORKMANSHIP AND TESTING (IGF CODE, 16)

Note:
Unless expressly provided otherwise, (the IGF Code parts B-1, …) Chapter 16 applies to ships using LPG as fuel. (MSC.1/Circ.1666, 16)

16.1 General (IGF Code, 16.1)

16.1.1 The manufacture, testing, inspection and documentation of structural materials shall be in accordance with recognized standards and the regulations given in this *Publication* (Code). (IGF Code, 16.1.1)

16.1.2 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat treated condition, in accordance with the applicable tables of Chapter 7, and the weld properties shall be determined in the heat treated condition in accordance with 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Administration. (IGF Code, 16.1.2)

16.2 General test regulations and specifications (IGF Code, 16.2)

16.2.1 Tensile test (IGF Code, 16.2.1)

16.2.1.1 Tensile testing shall be carried out in accordance with recognized standards. (IGF Code, 16.2.1.1)

16.2.1.2 Tensile strength, yield stress and elongation shall be to the satisfaction of the Administration. For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio. (IGF Code, 16.2.1.2)

16.2.2 Toughness test (IGF Code, 16.2.2)

16.2.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests unless otherwise specified by the Administration. The specified Charpy V-notch regulations are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens shall be in accordance with recognized standards. The testing and regulations for specimens smaller than 5.0 mm in size shall be in accordance with recognized standards. Minimum average values for sub-sized specimens shall be:

Charpy V-notch specimen size [mm]	Minimum average energy of three specimens
10 × 10	*KV*
10 × 7.5	5/6 *KV*
10 × 5.0	2/3 *KV*

where:
KV = the energy values (J) specified in tables 7.1 to 7.4.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value. (IGF Code, 16.2.2.1)

16.2.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in figure 16.1. (IGF Code, 16.2.2.2)

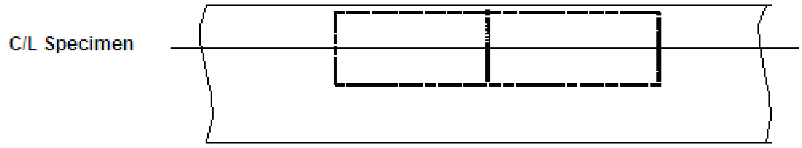

Figure 16.1. Orientation of base metal test specimen

16.2.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases the distance from the surface of the material to the edge of the specimen shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the following locations, as shown in figure 16.2, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.

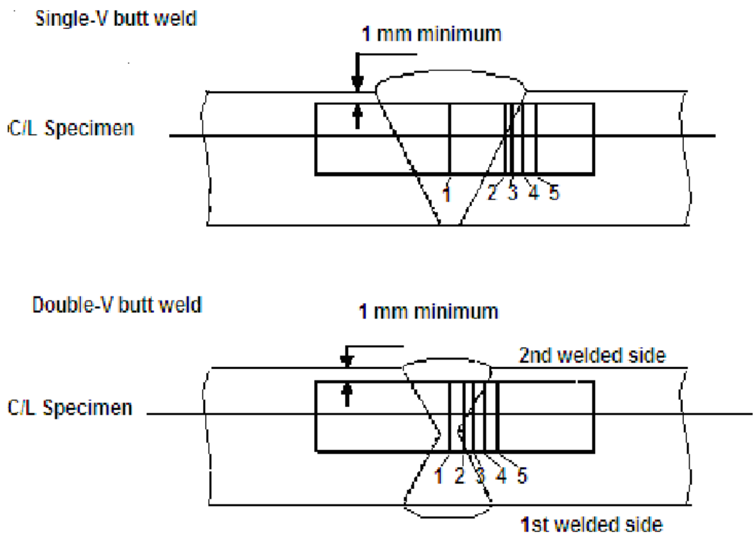

Figure 16.2. Orientation of weld test specimen

Notch locations in figure 16.2:

1 centreline of the weld;
2 on fusion line;
3 in heat-affected zone (HAZ), 1 mm from fusion line;
4 in HAZ, 3 mm from fusion line; and
5 in HAZ, 5 mm from fusion line. (IGF Code, 16.2.2.3)

16.2.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated regulations, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the regulations and if no more than two individual results are lower, than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted. (IGF Code, 16.2.2.4)

16.2.3 **Bend test** (IGF Code, 16.2.3)

16.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards. (IGF Code, 16.2.3.1)

16.2.3.2 The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Administration. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels. (IGF Code, 16.2.3.2)

16.2.4 Section observation and other testing

Macrosection, microsection observations and hardness tests may also be required by the Administration, and they shall be carried out in accordance with recognized standards, where required. (IGF Code, 16.2.4)

16.3 **Welding of metallic materials and non-destructive testing for the fuel containment system** (IGF Code, 16.3)

16.3.1 General

This section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of the Administration, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material. (IGF Code, 16.3.1)

16.3.2 Welding consumables

Consumables intended for welding of fuel tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information. (IGF Code, 16.3.2)

16.3.3 **Welding procedure tests for fuel tanks and process pressure vessels** (IGF Code, 16.3.1)

16.3.3.1 Welding procedure tests for fuel tanks and process pressure vessels are required for all butt welds. (IGF Code, 16.3.3.1)

16.3.3.2 The test assemblies shall be representative of:

.1 each base material;
.2 each type of consumable and welding process; and
.3 each welding position. (IGF Code, 16.3.3.2)

16.3.3.3 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator. (IGF Code, 16.3.3.3)

16.3.3.4 The following welding procedure tests for fuel tanks and process pressure vessels shall be done in accordance with 16.2 with specimens made from each test assembly:

.1 cross-weld tensile tests;
.2 longitudinal all-weld testing where required by the recognized standards;
.3 transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels;
.4 one set of three Charpy V-notch impacts, generally at each of the following locations, as shown in figure 16.2:

  .1 centreline of the welds;
  .2 fusion line;
  .3 1 mm from the fusion line;
  .4 3 mm from the fusion line; and
  .5 5 mm from the fusion line;

.5 macrosection, microsection and hardness survey may also be required. (IGF Code, 16.3.3.4)

16.3.3.5 Each test shall satisfy the following:

.1 tensile tests: cross-weld tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. For materials such as aluminium alloys, reference shall be made to 6.4.12.1.1.3 with regard to the regulations for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture shall be recorded for information;
.2 bend tests: no fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces; and
.3 Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal regulations for sub-size specimens and single energy values shall be in accordance with 16.2.2. The results of fusion line and heat affected zone impact tests shall show a minimum average energy (KV) in accordance with the transverse or longitudinal regulations of the base material, whichever is applicable, and for sub-size specimens, the minimum average energy (KV) shall be in accordance with 16.2.2. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards. (IGF Code, 16.3.3.5)

16.3.3.6 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties. (IGF Code, 16.3.3.6)

16.3.4 Welding procedure tests for piping

Welding procedure tests for piping shall be carried out and shall be similar to those detailed for fuel tanks in 16.3.3. (IGF Code, 16.3.4)

16.3.5 Production weld tests (IGF Code, 16.3.5)

16.3.5.1 For all fuel tanks and process pressure vessels except membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Administration. Tests, other than those specified in 16.3.5.2 to 16.3.5.5 may be required for fuel tanks or secondary barriers. (IGF Code, 16.3.5.1)

16.3.5.2 The production tests for types A and B independent tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch impact tests. The tests shall be made for each 50 m of weld. The Charpy V-notch impact tests shall be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the centre of the weld. (IGF Code, 16.3.5.2)

16.3.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 16.3.5.2. Tensile tests shall meet regulation 16.3.3.5. (IGF Code, 16.3.5.3)

16.3.5.4 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual (QM). (IGF Code, 16.3.5.4)

16.3.5.5 The test regulations for membrane tanks are the same as the applicable test regulations listed in 16.3.3. (IGF Code, 16.3.5.5)

16.3.6 Non-destructive testing (IGF Code, 16.3.6)

16.3.6.1 All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used in principle to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but in addition supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained. (IGF Code, 16.3.6.1)

16.3.6.2 For type A independent tanks where the design temperature is below –20°C, and for type B independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of fuel tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in 16.3.6.1. (IGF Code, 16.3.6.2)

16.3.6.3 In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods as considered necessary. (IGF Code, 16.3.6.3)

16.3.6.4 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:

.1 Total non-destructive testing referred to in 6.4.15.3.2.1.3

Radiographic testing:

.1 all butt welds over their full length.

Non-destructive testing for surface crack detection:

.2 all welds over 10% of their length;

.3 reinforcement rings around holes, nozzles, etc. over their full length.

As an alternative, ultrasonic testing, as described in 16.3.6.1, may be accepted as a partial substitute for the radiographic testing. In addition, the Administration may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

.2 Partial non-destructive testing referred to in 6.4.15.3.2.1.3:

Radiographic testing:

.1 all butt welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed.

Non-destructive testing for surface crack detection:

.2 reinforcement rings around holes, nozzles, etc. over their full length.

Ultrasonic testing:

.3 as may be required by the Administration in each instance. (IGF Code, 16.3.6.4)

16.3.6.5 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM). (IGF Code, 16.3.6.5)

16.3.6.6 Inspection of piping shall be carried out in accordance with the regulations of Chapter 7. (IGF Code, 16.3.6.6)

16.3.6.7 The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing. (IGF Code, 16.3.6.7)

16.4 Other regulations for construction in metallic materials (IGF Code, 16.4)

16.4.1 General

Inspection and non-destructive testing of welds shall be in accordance with regulations in 16.3.5 and 16.3.6. Where higher standards or tolerances are assumed in the design, they shall also be satisfied. (IGF Code, 16.4.1)

16.4.2 Independent tank

For type C tanks and type B tanks primarily constructed of bodies of revolution the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in 6.4.15.2.3.1 and 6.4.15.3.3.2. (IGF Code, 16.4.2)

16.4.3 Secondary barriers

During construction the regulations for testing and inspection of secondary barriers shall be approved or accepted by the Administration (see also 6.4.4.5 and 6.4.4.6). (IGF Code, 16.4.3)

16.4.4 Membrane tanks

The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme. (IGF Code, 16.4.4)

16.5 Testing (IGF Code, 16.5)

16.5.1 Testing and inspections during construction (IGF Code, 16.5.1)

16.5.1.1 All liquefied gas fuel tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 16.5.2 to 16.5.5, as applicable for the tank type. (IGF Code, 16.5.1.1)

16.5.1.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 16.5.1.1. (IGF Code, 16.5.1.2)

16.5.1.3 The gas tightness of the fuel containment system with reference to 6.3.3 shall be tested. (IGF Code, 16.5.1.3)

16.5.1.4 Regulations with respect to inspection of secondary barriers shall be decided by the Administration in each case, taking into account the accessibility of the barrier (see also 6.4.4). (IGF Code, 16.5.1.4)

16.5.1.5 The Administration may require that for ships fitted with novel type B independent tanks, or tanks designed according to 6.4.16 at least one prototype tank and its support shall be instrumented with strain gauges or other suitable equipment to confirm stress levels during the testing required in 16.5.1.1. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments. (IGF Code, 16.5.1.5)

16.5.1.6 The overall performance of the fuel containment system shall be verified for compliance with the design parameters during the first LNG bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements of the Administration. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained on board and be available to the Administration. (IGF Code, 16.5.1.6)

16.5.1.7 The fuel containment system shall be inspected for cold spots during or immediately following the first LNG bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with the requirements of the Administration. (IGF Code, 16.5.1.7)

16.5.1.8 Heating arrangements, if fitted in accordance with 6.4.13.1.1.3 and 6.4.13.1.1.4, shall be tested for required heat output and heat distribution. (IGF Code, 16.5.1.8)

16.5.2 Type A independent tanks

All type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation. (IGF Code, 16.5.2)

16.5.3 Type B independent tanks

Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing as follows:

.1 the test shall be performed as required in 16.5.2 for type A independent tanks.

.2 in addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment. (IGF Code, 16.5.3)

16.5.4 Type C independent tanks and other pressure vessels (IGF Code, 16.5.4)

16.5.4.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than $1.5P_0$. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield strength of the material at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels. (IGF Code, 16.5.4.1)

16.5.4.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated. (IGF Code, 16.5.4.2)

16.5.4.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours. (IGF Code, 16.5.4.3)

16.5.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 16.5.4.1 to 16.5.4.3. (IGF Code, 16.5.4.4)

16.5.4.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, regulation in 16.5.4.1 shall be fully complied with. (IGF Code, 16.5.4.5)

16.5.4.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in 16.5.4.1 or 16.5.4.4 as applicable. (IGF Code, 16.5.4.6)

16.5.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks shall be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated. (IGF Code, 16.5.4.7)

16.5.5 Membrane tanks (IGF Code, 16.5.5)

16.5.5.1 Design development testing (IGF Code, 16.5.5.1)

16.5.5.1.1 The design development testing required in 6.4.15.4.1.2 shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads at all filling levels. This will culminate in the construction of a prototype scaled model of the complete liquefied gas fuel containment system. Testing conditions considered in the analytical and physical model shall represent the most extreme service conditions the liquefied gas fuel containment system will be likely to encounter over its life.

Proposed acceptance criteria for periodic testing of secondary barriers required in 6.4.4 may be based on the results of testing carried out on the prototype scaled model. (IGF Code, 16.5.5.1.1)

16.5.5.1.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests. (IGF Code, 16.5.5.1.2)

16.5.5.2 Testing

.1 In ships fitted with membrane liquefied gas fuel containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.
.2 All hold structures supporting the membrane shall be tested for tightness before installation of the liquefied gas fuel containment system.
.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested. (IGF Code, 16.5.5.2)

16.6 Welding, post-weld heat treatment and non-destructive testing (IGF Code, 16.6)

16.6.1 General

Welding shall be carried out in accordance with 16.3. (IGF Code, 16.6.1)

16.6.2 Post-weld heat treatment

Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. the Administration may waive the regulations for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned. (IGF Code, 16.6.2)

16.6.3 Non-destructive testing

In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the regulations in this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with;

- **.1** design temperatures colder than minus 10°C; or
- **.2** design pressure greater than 1.0 MPa; or
- **.3** gas supply pipes in ESD protected machinery spaces; or
- **.4** inside diameters of more than 75 mm; or
- **.5** wall thicknesses greater than 10 mm.

.2 when such butt welded joints of piping sections are made by automatic welding procedures approved by the Administration, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed the extent of examination shall be increased to 100% and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently.
.3 the radiographic or ultrasonic inspection regulation may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.

.4 for other butt-welded joints of pipes not covered by 16.6.3.1 and 16.6.3.3, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection. (IGF Code, 16.6.3)

16.7 Testing requirements (IGF Code, 16.7)

16.7.1 Type testing of piping components (IGF Code, 16.7.1)

16.7.1.1 Valves

Each type of piping component intended to be used at a working temperature below minus 55°C shall be subject to the following type tests:

.1 each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of the Administration During the testing satisfactory operation of the valve shall be verified.

.2 the flow or capacity shall be certified to a recognized standard for each size and type of valve.

.3 pressurized components shall be pressure tested to at least 1.5 times the design pressure.

.4 for emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard at least equivalent to those acceptable to IMO*.

* Refer to the recommendations by the International Organization for Standardization, in particular publications: ISO 19921:2005, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.* ISO 19922:2005, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.*

16.7.1.2 Expansion bellows

The following type tests shall be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable in 7.3.6.4.3.1.3 and where required by the Administration, on those installed within the fuel tanks:

.1 elements of the bellows, not pre-compressed, but axially restrained shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.

.2 a pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.

.3 a cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.

.4 a cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced. (IGF Code, 16.7.2)

16.7.2 System testing (IGF Code, 16.7.3)

16.7.2.1 The regulations for testing in this section apply to fuel piping inside and outside the fuel tanks. However, relaxation from these regulations for piping inside fuel tanks and open ended piping may be accepted by the Administration. (IGF Code, 16.7.3.1)

16.7.2.2 After assembly, all fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1.5 times the design pressure. (IGF Code, 16.7.3.2)

16.7.2.3 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. (IGF Code, 16.7.3.3)

16.7.2.4 In double wall fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture. (IGF Code, 16.7.3.4)

16.7.2.5 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 Administration. (IGF Code, 16.7.3.5)

16.7.2.6 Emergency shutdown valves in liquefied gas piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable. (IGF Code, 16.7.3.6)

16.7.2.7 The closing time of the valve referred to in 8.5.8 and 15.4.2.2 (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than:

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

where:

U = ullage volume at operating signal level (m^3);
BR = maximum bunkering rate agreed between ship and shore facility (m^3/h); or 5 seconds, whichever is the least.

The bunkering rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant. (IGF Code, 16.7.3.7)

17 REQUIREMENTS FOR SHIPS USING HYDROGEN AS FUEL

17.1 Introduction

17.1.1 This Chapter is based on the IMO document CCC 9/WP.3 *Draft Interim Guidelines for Ships Using Hydrogen as Fuel*. Provisions of this document are marked with blue font and their original numbers (i.e. those from the *Draft Interim Guidelines*) are given in brackets at the end of each paragraph. PRS text is in black font.

These *Draft Interim Guidelines* (hereinafter referred to as *Interim Guidelines*) follow the goal-based approach (MSC.1/Circ.1394/Rev.2) by specifying goals and functional requirements for each section forming the basis for the design, construction and operation of ships using hydrogen as fuel. (1.4)

The current version of these *Interim Guidelines* includes provisions to meet the functional requirements for hydrogen as fuel. (1.5)

17.1.2 These *Interim Guidelines* have been closely aligned with the *International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels* (IGF Code), adopted by resolution MSC.391(95), as amended, in particular section 3 which is mainly text taken from Chapter 3 of the IGF Code. (1.6)

17.1.3 Ship's compliance with this Chapter is mandatory for the assignment of additional mark **IGF DF H_2** in the symbol of class. Compliance with selected provisions only will enable the assignment of additional mark **H_2 READY** in accordance with 2.1.4.

17.1.4 Ships using hydrogen fuel cells in combination with electric drive shall comply with Publication 37/I – *Guidelines for the safety of ships using fuel cell power installations*.

17.2 General (2)

17.2.1 *Application* (2.1)

Unless expressly provided otherwise, these *Interim Guidelines* apply to ships using liquified and/or compressed hydrogen as fuel to which part G of SOLAS Chapter II-1 applies.

17.2.2 *Definitions and abbreviations* (2.2)

Reference is made to the definitions provided in 2.2 (the *International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels* (IGF Code), adopted by resolution MSC 391(95), as amended, part A. 2.2). Additional definitions are provided below:

.1 ***Hydrogen consumer space*** means space containing energy converter(s) using hydrogen as fuel, including associated piping and auxiliaries, and fuel cell spaces where arranged as individual enclosures

.2 ***Compressed hydrogen*** means hydrogen in its gaseous state contained at any pressure above atmospheric pressure.

17.2.3 *Alternative design* (2.3)

17.2.3.1 These *Interim Guidelines* contain functional requirements for all appliances and arrangements related to the usage of hydrogen as fuel. (2.3.1)

17.2.3.2 Appliances and arrangements of hydrogen fuel systems may deviate from those set out in these *Interim Guidelines*, provided such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety to the relevant sections. (2.3.2)

17.2.3.3 The equivalence of the alternative design should be demonstrated as specified in SOLAS Regulation II-1/55 and approved by the Administration. However, the Administration should 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 these *Interim Guidelines*.(2.3.3) See also 1.7.

17.3 Goal and functional requirements (3)

17.3.1 *Goal* (3.1)

The goal of these *Interim Guidelines* is to provide for safe and environmentally-friendly design, construction and operation of ships using hydrogen as fuel, in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery.

17.3.2 *Functional requirements* (3.2)

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

17.3.2.2 The probability and consequences of fuel-related hazards should 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 should be initiated. (3.2.2)

17.3.2.3 The design philosophy should ensure that risk reducing measures and safety actions for the hydrogen fuel installation do not lead to an unacceptable loss of power. (3.2.3)

17.3.2.4 Hazardous areas should 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)

17.3.2.5 Equipment installed in hazardous areas should be minimized to that required for operational purposes and should be suitably and appropriately certified. (3.2.5)

17.3.2.6 Unintended accumulation of explosive, flammable or harmful gas concentrations should be prevented. (3.2.6)

17.3.2.7 System components should be protected against external damages. (3.2.7)

17.3.2.8 Sources of ignition in hazardous areas should be minimized to reduce the probability of explosions. (3.2.8)

17.3.2.9 It should be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system should be designed to prevent venting under all normal operating conditions including idle periods. (3.2.9)

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

17.3.2.11 Machinery, systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation. (3.2.11)

17.3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space should be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable. (3.2.12)

17.3.2.13 Suitable control, alarm, monitoring and shutdown systems should be provided to ensure safe and reliable operation. (3.2.13)

17.3.2.14 Fixed gas detection suitable for all spaces and areas concerned should be arranged. (3.2.14)

17.3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned should be provided. (3.2.15)

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

17.3.2.17 The technical documentation should 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. (3.2.17)

17.3.2.18 A single failure in a technical system or component should not lead to an unsafe or unreliable situation. (3.2.18)

17.3.2.19 Measures should be taken to prevent excessive oxygen/nitrogen concentrations caused by condensation and enrichment at low temperatures. (3.2.19)

17.4 General requirements (4)

17.4.1 *Goal* (4.1)

The goal of this Section 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.

17.4.2 *Risk assessment* (4.2)

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

17.4.2.2 The risk assessment should specifically consider the hydrogen system integrity with focus on its ability to prevent and isolate leakages and also evaluate potential ignition mechanisms and consequences of ignition. Special consideration should be given, but not limited to, the following specific hydrogen related hazards and topics:

- leaks;
- loss of functions;
- component damage;
- fire (including escalating events);

- explosion analysis;
- material properties related to permeation, cryogenic temperatures, and/or high pressures;
- bunkering station and operation;
- gas and fire detection;
- fire-extinguishing;
- enclosed spaces with hydrogen piping and/or equipment (including geometry and obstructions related to accumulation of hydrogen and increased turbulence);
- ignition sources;
- self-ignition;
- control, alarm and safety systems;
- vent mast design;
- ventilation rates (including induced risk from circulated humid air and likelihood for detection of small leaks); and
- condensation of air (liquid hydrogen). (4.2.2)

17.4.2.3 The risks should be analysed using acceptable and recognized risk analysis techniques*. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be documented to the satisfaction of the Administration. (4.2.3)

* See IACS REC. 146 - *Risk assessment as required by the IGF Code*. Please note that REC. 146 provides recommended practice of risk assessment but it makes use of LNG properties for the assessment. Hydrogen properties are provided at the end of this Chapter 17.

17.4.3 *Limitation of explosion consequences* (4.3)

An explosion in any space containing any potential sources of release* and potential ignition sources should not:

.1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;
.2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;
.3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;
.4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;
.5 damage life-saving equipment or associated launching arrangements;
.6 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;
.7 affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or
.8 prevent persons access to life-saving appliances or impede escape routes.

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

17.5 Ship design and arrangement (5)

17.5.1 *Goal* (5.1)

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

17.5.2 ***Functional requirements*** (5.2)

17.5.2.1 This Chapter is related to functional requirements in 17.3.2.1 to 17.3.2.3, 17.3.2.5, 17.3.2.6, 17.3.2.8, 17.3.2.12 to 17.3.2.15 and 17.3.2.17. In particular, the following apply:

.1 the fuel tank(s) should be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;
.2 fuel containment systems, fuel piping and other fuel sources of release should be so located and arranged that released hydrogen is led to a safe location in the open air;
.3 the access or other openings to spaces containing hydrogen sources of release should be so arranged that flammable or, asphyxiating gas cannot escape to spaces that are not designed for the presence of such gases;
.4 fuel piping should be protected against mechanical damage;
.5 the propulsion and hydrogen supply system should be so designed that safety actions after any hydrogen leakage do not lead to an unacceptable loss of power; and
.6 the probability of a hydrogen explosion in a machinery space with hydrogen or low-flashpoint fuelled machinery should be minimized. (5.2.1)

17.5.3 ***General provisions*** (5.3)

17.5.3.1 Unless expressly provided otherwise, the requirements of this *Publication* (IGF Code part A-1) Chapter 5 apply. (5.3.1)

17.5.4 ***Machinery space concept*** (5.4)

17.5.4.1 In addition to 5.4 of this *Publication* (IGF Code), a single failure of fuel systems should not lead to a gas release in the machinery space, i.e. only gas-safe machinery space concept in accordance with this *Publication* (IGF Code) should be accepted. (5.4.1)

17.5.4.2 The requirements of 5.6 of this *Publication* (IGF Code)do not apply to ships using hydrogen as fuel. ESD-protected machinery spaces may be permitted, provided that the requirements of alternative design (SOLAS II-1/55) are met to the satisfaction of the Administration. (5.4.2) See also 1.7.

17.5.5 ***Ship arrangement principles*** (5.5)

17.5.5.1 Fuel cells should be arranged in accordance with the *Interim Guidelines for the safety of ships using fuel cell power installations* (MSC.1/Circ.1647). (5.5.1) See also 17.1.4.

17.5.6 ***Provisions for location and protection of fuel piping*** (5.6)

17.5.6.1 Fuel pipes should not be located less than 800 mm from the side shell, which includes the aft end of the ship. (5.6.1)

17.5.6.2 Fuel piping should not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention. (5.6.2)

17.5.6.3 Fuel pipes led through ro-ro spaces, special category spaces and on open decks should be protected against mechanical damage. (5.6.3)

17.5.6.4 Cryogenic external surfaces of hydrogen piping should be protected against exposure to air to prevent condensation of nitrogen or oxygen. (5.6.4)

17.5.7 Intentionally left blank.

17.5.8 *Fuel preparation rooms*

Fuel preparation rooms should as a minimum fulfil the requirements given in section 5.8 of this *Publication* (the IGF Code) unless specified in this section. The equipment of fuel preparation rooms should be located in an area on the open deck area providing natural ventilation and unobstructed relief of leakages.

If such equipment is to be arranged in an enclosure or in a space below deck, then the arrangement should be subject to the special consideration and satisfaction of the Administration. The approval of such arrangements should take into account, but not limited to:

- Inerted space;
- Access;
- Self ignition;
- Delayed ignition;
- Condensation of inert gas in case of single failure;
- Fire protection;
- Explosion relief. (5.8.2)

17.5.9 *Provisions for bilge systems* (5.9)

17.5.9.1 Bilge systems installed in areas where hydrogen can be present should be segregated from the bilge system of spaces where hydrogen cannot be present. (5.9.1)

17.5.9.2 Where hydrogen is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any liquid leakage into the hold, inter-barrier or insulation spaces should be provided. The bilge system should not lead to pumps in safe spaces. Means of detecting such leakage should be provided. (5.9.2)

17.5.9.3 Bilge systems for fuel hold spaces not considered hazardous but arranged with inerted atmosphere should be segregated from the bilge system for other spaces. (5.9.3)

17.5.10 *Provisions for drip trays* (5.10)

17.5.10.1 Drip trays should be fitted where hydrogen leakage or condensation of air may occur which can cause damage to the ship structure, where limitation of the area which is affected from a spill is necessary, or where condensated air due to a cold gas release otherwise may impinge on ship structures. (5.10.1)

17.5.10.2 Drip trays should be made of suitable material. (5.10.2)

17.5.10.3 The drip tray should be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel. (5.10.3)

17.5.10.4 Each tray should be fitted with a drain valve to enable rainwater to be drained over the ship's side. (5.10.4)

17.5.10.5 Each tray should have a sufficient volume and thermal capacity to ensure that the maximum amount of spill according to the risk assessment can be handled (see 17.4.2). (5.10.5)

17.5.11 ***Provisions for arrangement of entrances and other openings in enclosed spaces*** (5.11)

17.5.11.1 Direct access should not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 17.5.12 should be provided. (5.11.1)

17.5.11.2 If the fuel preparation room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 17.5.12 should be provided. (5.11.2)

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

17.5.11.4 If the ESD-protected machinery space is approved and access is arranged from another enclosed space in the ship, the entrances should be arranged with an airlock which complies with 17.5.12. (5.11.4)

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

17.5.12 ***Provisions for airlocks*** (5.12)

17.5.12.1 An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of the *International Convention on Load Lines*, the door sill should not be less than 300 mm in height. The doors should be self-closing without any holding back arrangements. (5.12.1)

17.5.12.2 Airlocks should be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space. (5.12.2)

17.5.12.3 The airlock should be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events should be evaluated in the risk analysis according to 17.4.2. (5.12.3)

17.5.12.4 Airlocks should have a suitable geometrical form promoting elimination of accumulated hydrogen. (5.12.4)

17.5.12.5 Airlocks should provide free and easy passage of personnel, and should have a deck area not less than 1.5 m^2. Airlocks should not be used for other purposes, for instance as store rooms. (5.12.5)

17.5.12.6 An audible and visual alarm system to give a warning on both sides of the airlock should be provided to indicate if more than one door is moved from the closed position. (5.12.6)

17.5.12.7 For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space should be restricted until the ventilation has been reinstated. Audible and visual alarms should 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)

17.5.12.8 Essential equipment required for safety should not be de-energized and should be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems. (5.12.8)

17.5.13 ***Storage arrangements for compressed and liquified hydrogen*** (5.13)

17.5.13.1 Hydrogen storage should not be located in enclosed spaces. (5.13.1)

17.5.13.2 Notwithstanding 17.5.13.1, hydrogen storage may be permitted in enclosed spaces after special consideration and approval by the Administration. Measures for compressed hydrogen storage should include:

.1 Adequate ventilation should be provided for any space containing compressed hydrogen storage tanks to avoid accumulation of flammable concentrations due to permeation of hydrogen;
.2 Adequate fire detection and mitigating measures need to be provided in the enclosed spaces containing compressed hydrogen storage tanks; (5.13.2)

17.5.13.3 As an alternative to 17.5.13.2.1 and 17.5.13.2.2, adequate inerting with monitoring may be provided for any space containing compressed hydrogen storage tanks to address accumulation of hydrogen due to permeation. (5.13.3)

17.5.13.4 The location of hydrogen fuel containment systems in the ship should be considered under the risk assessment as set out in 17.4.2, which may lead to additional safety measures for integration into the overall ship design. (5.13.4)

17.6 Fuel containment system (6)

17.6.1 ***Goal*** (6.1)

The goal of this Chapter is to provide that hydrogen 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

17.6.2 ***Functional requirements*** (6.2)

This Chapter relates to functional requirements in 17.3.2.1, 17.3.2.2, 17.3.2.5 and 17.3.2.8 to 17.3.2.17.

In particular the following apply:

.1 the fuel containment system should 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 formation of ice from moisture in the air;
  .2 formation of frozen or liquified air;
  .3 exposure of ship materials to temperatures below acceptable limits;
  .4 fuel leaking to form a flammable or explosive atmosphere;
  .5 risk of oxygen deficiency due to fuel and inert gases;
  .6 flammable fuels spreading to locations with ignition sources;

  .7 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and
  .8 reduction in availability of LSA.

.2 the pressure and temperature in the fuel tank should be kept within the design limits of the containment system and possible carriage requirements of the fuel;
.3 the fuel containment arrangement should be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and
.4 if portable tanks are used for fuel storage, the design of the fuel containment system should be equivalent to that of permanent installed tanks as described in this Chapter.

17.6.3 ***General provisions for fuel containment systems*** (6.3)

17.6.3.1 Unless expressly provided otherwise, the requirements of section 17.6.3 of this *Publication* (the IGF Code) should apply to ships using hydrogen as fuel. (6.3.1)

17.6.3.2 Hydrogen storage tanks, including any related tank connection spaces where fitted, should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages. (6.3.2)

17.6.3.3 In addition to 6.3.12 of this *Publication* (the IGF Code), an appropriate procedure should be established for warm-up, inert gas purge, gas-free, hydrogen purge and pre-cooling. The procedure should as a minimum include:

.1 selection of inert gas in relation to temperature limit;
.2 measurement of gas concentration;
.3 measurement of temperature;
.4 rates of supply of gases;
.5 conditions for commencement, suspension, resuming and termination of each operation;
.6 treatment of return gases; and
.7 discharge of gases. (6.3.3)

17.6.4 ***Provisions for liquefied gas fuel containment*** (6.4)

17.6.4.1 Unless expressly provided otherwise, the requirements of section 6.4 of this *Publication* (the IGF Code) should apply to ships using hydrogen as fuel. (6.4.1)

17.6.4.2 Liquified hydrogen storage tanks, including any related tank connection spaces where fitted, should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages. (6.4.2)

17.6.4.3 If such equipment is to be arranged in an in an enclosed or semi-enclosed space, then the arrangement should provide unobstructed relief of leakages and should be subject to special consideration by the Administration. The approval of such arrangements should take into account, as a minimum, the following specific hydrogen-related hazards and topics:

– hydrogen system pressure;
– possibility of inerting the space;
– condensation of inert gas in case of leakage;
– self-ignition;
– delayed ignition;
– fire protection, including detection;
– oxygen enrichment;

- explosion relief;
- segregation towards other areas on the ship;
- hazardous area plans for the ship;
- forced ventilation;
- leakage detection;
- safety actions related to leakage;
- preventing deposits of liquified or solidified air;
- access to the space from non-hazardous areas through airlocks; and
- monitoring of spaces by a closed circuit television (CCTV). (6.4.3)

17.6.4.4 In addition to 6.4.8 of this *Publication* (the IGF Code), the following provisions regarding thermal insulation apply: (6.4.4)

17.6.4.4.1 When deterioration of insulation capability by single damage is possible, appropriate safety measures should be adopted taking into account the deterioration. For vacuum insulated tanks, the pressure relief valves capacity and associated piping should be dimensioned for a simultaneous fire heat load, based on the outcome of risk assessment (see 17.4.2), and loss of insulation. (6.4.4.1)

17.6.4.4.2 When vacuum insulation is used for a fuel containment system, the insulation performance should be evaluated to the satisfaction of the Administration. (6.4.4.2)

17.6.4.5 In addition to 6.4.14 of this *Publication* (the IGF Code), all welded joints of the shells of fuel tanks should 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. (6.4.5)

17.6.4.6 Piping connected to the tank should be protected by a secondary barrier up to the first valve. (6.4.6)

17.6.5 ***Provisions for portable liquefied hydrogen tanks*** (6.5)

17.6.5.1 The design of the tank should comply with 6.4.15.3 of this *Publication* (the IGF Code). The tank support (container frame or truck chassis) should be designed for the intended purpose. (6.5.1)

17.6.5.2 Portable fuel tanks should be located in dedicated areas fitted with:

.1 mechanical protection of the tanks depending on location and cargo operations;
.2 if located on open deck: spill protection and water spray systems for cooling; and
.3 if located in an enclosed or semi-enclosed space the provisions of 17.6.4.3 should apply. In addition to the list of items to be considered for approval, flexible hoses and tank connections should be considered. (6.5.2)

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

17.6.5.4 Consideration should be given to the strength and the effect of the portable fuel tanks on the ship's stability. (6.5.4)

17.6.5.5 Connections to the ship's fuel piping systems should be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility. The selection of flexible hoses should take into account the suitability for their use in hydrogen service. (6.5.5)

17.6.5.6 The connections at the tank should be arranged in order to achieve a dry disconnect operation. If the risk assessment (see 17.4.2)so indicates, the tank should also be equipped with additional break-away coupling/self-sealing quick release. Arrangements should be provided to limit the quantity of fuel spilled in case of inadvertent disconnection or rupture of the non-permanent connections. (6.5.6)

17.6.5.7 The pressure relief system of portable tanks should be connected to a fixed venting system. (6.5.7)

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

17.6.5.9 Safe access to tank connections for the purpose of inspection and maintenance should be ensured. (6.5.9)

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

- **.1** with the exception of the pressure relief system in 17.6.5.7, each portable tank should be capable of being isolated at any time;
- **.2** isolation of one tank should not impair the availability of the remaining portable tanks; and
- **.3** the tank should not exceed its filling limits as given in this *Publication* (the IGF Code) section 6.8. (6.5.10)

17.6.6 ***Provisions for compressed hydrogen storage*** (6.6)

17.6.6.1 The construction of compressed hydrogen tanks should be to a standard acceptable to the Administration. Tanks of other materials than steel, for example composite or cylindrical wound cylinders, or tanks constructed to other standards than marine standards, should be specially considered. (6.6.1)

17.6.6.2 Compressed hydrogen tanks should be provided with a suitable pressure-relief device, taking into account the design and construction of the tank. (6.6.2)

17.6.6.3 Adequate means should be provided to depressurize the tank in case of a fire which can affect the tank. This may include temperature-actuated safety relief systems, e.g. thermal pressure relief devices. The relieving capacity and area of the safety relief devices should be designed and calculated to ensure the rated capacity. (6.6.3)

17.6.6.4 Storage tanks used for compressed hydrogen, including any related tank connection spaces where fitted, should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages. (6.6.4)

17.6.6.5 If such equipment is to be arranged in an enclosed or semi-enclosed space, then the arrangement should provide unobstructed relief of leakages and should be subject to special consideration by the Administration. The approval of such arrangements should take into account, as a minimum, the following specific hydrogen-related hazards and topics:

- hydrogen system pressure;
- inerting of the space;
- permeation of hydrogen into the space;
- self-ignition;
- delayed ignition;
- fire protection, including detection;
- preventing jet-fires;
- explosion relief;
- segregation towards other areas on the ship;
- hazardous area plans for the ship;
- leakage detection;
- safety actions related to leakage;
- access to the space. (6.6.5)

Important note:
Below remaining provisions of subchapter 17.6 are not complete and definitive, therefore topics covered by these provisions will be subject to special consideration by PRS and additional requirements may be applied.

17.6.6.5.1 ***Compressed hydrogen tank venting systems*** (6.6.4)

17.6.6.5.1.1 The outlet of a fuel tank safety relief device should be connected to the ship's gas fuel venting system, and the outlet from the venting system should be:

.1 so constructed that the discharge will be unimpeded and be directed vertically upwards at the exit;
.2 arranged to minimize the possibility of water or snow entering the vent system;
.3 provided with a flame arrester;
.4 arranged such that the height of vent exits is normally not to be less than B/3 or 6 m, whichever is greater; and
.5 located at least 10 m from the nearest air intake, air outlet or opening to accommodation, service and control spaces, or exhaust outlet from machinery installations. (6.6.4.1)

17.6.6.5.1.2 The fuel gas venting system is to be independent of those of accommodation, service and control spaces, or other non-hazardous areas. (6.6.4.2)

17.6.6.5.1.3 All vent piping is to be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions. (6.6.4.3)

17.6.7 ***Provisions for pressure relief systems*** (6.7)

17.6.7.1 All fuel storage tanks should 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, inter-barrier spaces and tank connection spaces, which may be subject to pressures beyond their design capabilities, should also be provided with a suitable pressure relief system. Pressure control systems specified in this *Publication* (IGF Code) section 6.9 shall be independent of the pressure relief systems. (6.7.1)

17.6.7.2 This *Publication* (IGF Code) section 6.7 should be taken into account for the design of pressure relief systems of hydrogen fuel storage systems. (6.7.2)

17.6.8 ***Provisions on loading limit for liquefied hydrogen tanks*** (6.8)

17.6.8.1 The provisions of this *Publication* (IGF Code) section 6.8 should apply to liquefied hydrogen tanks. (6.8.1)

17.6.8.2 Storage tanks for liquefied hydrogen should not be filled to more than a volume equivalent to 98% full at the reference temperature. (6.8.2)

17.6.9 ***Provisions for the maintaining of fuel storage condition*** (6.9)

17.6.9.1 The liquefied gas fuel tanks should be designed in accordance with 6.9 of this *Publication* (the IGF Code). (6.9.1)

17.6.10 ***Provisions on atmospheric control within the fuel containment system*** (6.10)

17.6.10.1 The provisions of section 6.10 of this *Publication* (the IGF Code) should apply. (6.10.1)

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

17.6.11.1 The provisions of section 6.11 of this *Publication* (the IGF Code) should apply. (6.11.1)

17.6.12 ***Provisions on environmental control of spaces surrounding type C independent tanks*** (6.12)

17.6.12.1 Spaces surrounding hydrogen tanks should be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This is only applicable for liquefied hydrogen tanks where condensation and icing due to cold surfaces is an issue. (6.12.1)

17.6.13 ***Provisions on inerting*** (6.13)

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

17.6.13.2 To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line should be fitted with two shut-off valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve should be installed between the double block and bleed arrangement and the fuel system. These valves should be located outside non-hazardous spaces. (6.13.2)

17.6.13.3 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in 17.6.13.2. (6.13.3)

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

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

17.6.14 ***Provisions on inert gas production and storage on board*** (6.14)

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

17.6.14.2 An inert gas system should have pressure controls and monitoring arrangements appropriate to the fuel containment system. (6.14.2)

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

17.6.14.4 Nitrogen pipes should only be led through well ventilated spaces. Nitrogen pipes in enclosed spaces should:

- be fully welded;
- have only a minimum of flange connections as needed for fitting of valves; and
- be as short as possible. (6.14.4)

17.7 Material and general pipe design (7)

17.7.1 *Goal* (7.1)

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

17.7.2 *Functional requirements* (7.2)

Chapter 7 of this *Publication* (the IGF Code) should be taken into account.

17.7.2.1 This Chapter relates to functional requirements in 17.3.2.1, 17.3.2.5, 17.3.2.6, 17.3.2.8, 17.3.2.9 and 17.3.2.10. In particular, the following apply: (7.2.1)

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

17.7.2.1.2 Provision should be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure. (7.2.1.2)

17.7.2.1.3 Provisions should be made to minimize the likelihood and size of a leak from the piping system. (7.2.1.3)

17.7.2.1.4 Low temperature piping should 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. (7.2.1.4)

17.7.2.1.5 Materials used in all components in contact with hydrogen should withstand phenomena such as, but not limited to, hydrogen embrittlement, hydrogen permeation and hydrogen attack. (7.2.1.5)

17.7.3 *General* (7.3)

17.7.3.1 The materials to be used in hydrogen systems should be suitable for the medium and service for which the system is intended. This should be proven either by selection of materials according to 17.7.3.2 to 17.7.3.5, a recognized standard specifying the suitability of the material for the medium and service intended, or by adequate qualification testing, see below: (7.3.1)

17.7.3.2 Test scope for qualification of a material should be acceptable to the Administration. The qualification of metallic materials by testing should address:

.1 the degradation of the material properties due to exposure to hydrogen, where degradation is expected to increase with increasing temperature and pressure
.2 the degradation of the material properties due to cryogenic temperature, where degradation is expected to increase with decreasing temperature
.3 the combined effect of these[1]. (7.3.2)

[1] See Susceptibility of materials to embrittlement in hydrogen at 10, 000 psi and 72°F (~22°C) in the ANSI/AIAA G-095-2004 *Guide to Safety of Hydrogen and Hydrogen Systems*.

17.7.3.3 Typical properties to be considered are yield stress, tensile strength, ductility, fracture toughness, fatigue properties, hydrogen embrittlement, hydrogen permeation properties, corrosion resistance (as relevant) and coefficient of thermal expansion. (7.3.3)

17.7.3.4 Where materials are intended to be further processed/fabricated by forming or welding, the impact of the processing on the relevant properties should be considered. (7.3.4)

17.7.3.5 Fuel pipes should be seamless steel pipe and made of austenitic stainless steel. Materials used for pipes with a design pressure of 20MPa or above are to be, for example, but not limited to S31603 or S31608 stainless steel. (7.3.5)

17.7.4 *Metallic materials* (7.4)

17.7.4.1 Metallic materials to be used in hydrogen systems should be suitable for their intended use[2]. (7.4.1)

[2] See relevant NASA or AIAA Guidelines if any.

17.7.4.2 The base metal of clad materials used for hydrogen tank construction should be an acceptable material for liquid hydrogen service. The thickness used in pressure design should not include the thickness of the clad or lining. (7.4.2)

17.7.4.3 The allowable stress used should be that for the base metal at the design temperature. (7.4.3)

17.7.5 *Non-metallic materials* (7.5)

Non-metallic materials to be used in hydrogen systems should be suitable for their intended use[3]. Coefficients of thermal expansion (CTE) and permeation by hydrogen should be considered when choosing composite materials. Fire resistance properties should be considered for use in gaskets, packing or other sealing elements (e.g. spacers).

[3] See relevant NASA or AIAA Guidelines, if any.

17.8 Bunkering (8)

17.8.1 *Goal* (8.1)

17.8.1.1 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. (8.1.1)

17.8.2 ***Functional requirements*** (8.2)

Chapter 8 of this *Publication* (the IGF Code) should be taken into account.

17.8.2.1 This Chapter relates to functional requirements in 17.3.2.1 to 17.3.2.11, 17.3.2.13 to 17.3.2.17 and 17.3.2.19. In particular, the following apply: (8. 1)

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

17.8.2.1.2 Bunkering lines and manifolds should be protected from mechanical damage. (8.2.1.2)

17.8.3 ***Bunkering stations*** (8.3)

17.8.3.1 Bunkering stations should be located in an area on the open deck providing natural ventilation and unobstructed relief of leakages. (8.3.1)

17.8.3.2 If bunkering stations are arranged in an enclosed or semi-enclosed space, then the arrangement should provide unobstructed relief of leakages and should be subject to special consideration by the Administration. The approval of such arrangements should take into account, as a minimum, the following specific hydrogen-related hazards and topics:

- self ignition;
- delayed ignition;
- fire protection, including detection;
- oxygen enrichment;
- explosion relief;
- segregation towards other areas on the ship;
- hazardous area plans for the ship;
- forced ventilation;
- leakage detection;
- safety actions related to leakage;
- preventing deposits of liquified or solidified air;
- access to bunkering station from non-hazardous areas through airlocks; and
- monitoring of bunkering station by direct line of sight or by a closed circuit television (CCTV). (8.3.2)

17.8.3.3 The bulkheads of enclosed or semi-enclosed bunkering stations should be gas tight to avoid spreading of hydrogen gas into adjacent enclosed spaces. (8.3.3)

17.8.3.4 Control of the bunkering should be possible from a safe location. At this location the tank pressure and tank temperature should be monitored. High temperature and high-pressure alarm, automatic and manual shutdown should also be indicated at this location. (8.3.4)

17.8.3.5 Bunkering lines should not pass through accommodation spaces, control stations or service spaces. (8.3.5)

17.8.3.6 Bunkering lines should not pass through other enclosed spaces unless they are arranged as double-wall pipes with vacuum or inert gas in the annular space. (8.3.6)

17.8.4 *Bunkering manifolds* (8.4)

17.8.4.1 The bunkering manifold should be designed to withstand the external loads during bunkering. (8.4.1)

17.8.4.2 The bunkering coupling should be appropriate for fuel bunkering operations and capable of withstanding the design temperature and design pressure. (8.4.2)

17.8.4.3 The connections at the bunkering station should be arranged in order to achieve a dry disconnect operation. (8.4.3)

17.8.4.4 Connections should be equipped with additional break-away coupling/self-sealing quick release. (8.4.4)

17.8.5 *Bunkering systems* (8.5)

17.8.5.1 The fuel tank should not exceed the maximum design temperature during bunkering operations. (8.5.1)

17.8.5.2 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve should be fitted in every bunkering line close to the connecting point. It should be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location. (8.5.2)

17.8.5.3 Bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes should be free of gas, unless the consequences of not gas freeing are evaluated and approved. (8.5.3)

17.8.5.4 Where bunkering pipes are arranged with a crossover, suitable isolation arrangements should be provided that fuel cannot be transferred inadvertently to the ship side not in use for bunkering. (8.5.4)

17.8.5.5 A bunkering safety link or an equivalent means for automatic and manual ESD communication to the bunkering source should be fitted. (8.5.5)

17.8.5.6 The provisions mentioned in this Chapter should also apply to bunkering systems as connections to portable hydrogen tanks. (8.5.6)

Important note:
Below remaining provisions of subchapters 17.9 to 17.15 are not complete and definitive, therefore topics covered by these provisions will be subject to special consideration by PRS and additional requirements may be applied.

17.9 Fuel supply to consumers (9)

17.9.1 *Goal* (9.1)

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

17.9.2 *Functional requirements* (9.2)

This Chapter is related to functional requirements in 17.3.2.1 to 17.3.2.6, 17.3.2.8 to 17.3.2.11 and 17.3.2.13 to 17.3.2.17. In particular, the following apply:

17.9.3 ***Piping system design principles*** (9.3)

17.9.3.1 The fuel piping system should as a minimum fulfil the requirements given in this *Publication* (the IGF Code) paragraphs 7.1, 7.2 and 7.3. (9.3.1)

17.9.3.2 The material selection of piping and valves in the fuel system should comply with the applicable parts of section 17.6 of these *Interim Guidelines*. (9.3.2)

17.9.3.3 The liquid and compressed hydrogen fuel supply lines towards the consumers and bunkering lines on board the ship, both on open deck, semi-enclosed spaces, and spaces below deck (enclosed space), are recommended to be double walled (pipe-in-pipe). This applies from the liquid and compressed hydrogen bunkering station/bunkering coupling to the ship fuel-storage system, including to tank connection space(s), fuel preparation room and hydrogen consumer space. (9.3.3)

17.9.3.4 It is recommended to use as small operating pressure as possible, and flow restriction on high pressure pipe work, in order to minimize mass flow of hydrogen and hence the consequences of any unintended releases. (9.3.4)

17.9.3.5 Pipe segments should be as short as possible in length. (9.3.5)

17.9.3.6 Liquid and gas hydrogen pipes except for bunkering lines (see 17.8.3.5 and 17.8.3.6) should not pass through enclosed spaces, such as through accommodation spaces, service spaces, electrical equipment rooms, control stations or inside double bottom if fitted. Unless:

.1 the spaces are equipped with gas detection systems which activate the alarm at not more than 30% LFL and shut down the isolation valves, as appropriate, at not more than 60% LFL; and
.2 the spaces are adequately ventilated; or
.3 the spaces are maintained in an inert condition. (9.3.6)

17.9.3.7 This requirement is not applicable to spaces constituting a part of a cargo containment system using vacuum insulation where the degree of vacuum is monitored. (9.3.7)

17.9.3.8 The piping in the fuel system, including bunkering line, should as far as practicably possible be located and routed along the centre of the vessel. It is advised that the collision/grounding and hydrogen storage system damage risks are evaluated early in the design process considering that the impact of, for example, collision or other external risks (e.g. dropped objects) to the hydrogen piping system may have a high (near 100%) probability of generating a fire and/or explosion. (9.3.8)

17.9.3.9 For fuel pipes containing liquid hydrogen and cold hydrogen vapour, measures should be taken to prevent the exposed surfaces from reaching -183°C. For places where preventive measures against low temperature are not sufficiently effective, such as bunkering manifolds, other appropriate measures such as ventilation which avoids the formation of highly enriched oxygen and the installation of trays recovering liquid air may be permitted in lieu of the preventive measures. Insulation on liquid hydrogen piping systems exposing to air should be of non-combustible material and should be designed to have a seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation. (9.3.9)

17.9.3.10 The design of piping system for low-temperature service should account for the stress caused in components by thermal expansion and contraction. Hence, the fuel piping should be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses. Proper design should accommodate the thermal expansion of the different materials involved. (9.3.10)

17.9.3.11 Provision should be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to environmental loads and from movements of the tank and hull structure. (9.3.11)

17.9.3.12 The arrangement and installation of fuel piping should provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account. Fatigue loads are specially to be considered when installing hydrogen piping systems on high-speed craft (*High-Speed Craft Code* – HSC Code). (9.3.12)

17.9.3.13 A complete pipe stress analysis applying the principles given in ASME B31.3, 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 should be carried out for hydrogen piping regardless of operating temperatures and design conditions of the piping system. (9.3.13)

17.9.3.14 Inherently safe piping systems should be arranged. A single pipe leak or pipe fitting leak may lead to an unacceptable scenario. (9.3.14)

17.9.3.15 Full pipe rupture should be considered as the leakage case. Any physical restrictions around the hydrogen piping should be included in explosion simulations since hydrogen explosions are greatly impacted by physical boundaries. (9.3.15)

17.9.3.16 For engines using gas as the only fuel, the fuel supply system should be arranged with redundancy and segregation. A leakage in the fuel supply system with following necessary safety actions should not lead to an unacceptable loss of power. (9.3.16)

17.9.3.17 An FMEA should be carried out and it should cover any single failure in active components or systems. (9.3.17)

17.9.4 ***Fuel piping systems containing cryogenic liquids*** (9.4)

17.9.4.1 The liquid hydrogen supply and bunkering lines should have a design pressure not less than 20 bar, and the liquid hydrogen gaseous supply lines should have a design pressure not less than 10 bar. This applies for fuel piping located both on open deck and below deck (enclosed spaces). The pressure limits may be subject to discussion. (9.3.1)

17.9.4.2 Secondary enclosures ensuring no leakage should be provided for places where leakage of hydrogen may occur, such as valves, flanges, and seals. Bolted flange connections of hydrogen piping should be avoided where welded connections are feasible. (9.4.2)

17.9.4.3 The secondary enclosure should be made of a material that can withstand the temperature of the potential leak. (9.4.3)

17.9.4.4 The secondary enclosure should be provided with a vacuum insulated arrangement, a mechanical ventilation system or an inert gas system. (9.4.4)

17.9.4.5 The tank connections for liquid hydrogen piping systems should preferably be located above the highest liquid level for fuel tanks of type C. (9.4.5)

17.9.4.6 Low temperature piping and components (especially for liquid hydrogen and cold gaseous hydrogen) to be thermally insulated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. (9.4.6)

17.9.5 ***Fuel piping systems containing gaseous fuels*** (9.5)

17.9.5.1 Secondary enclosures ensuring no leakage should be provided for places where leakage of hydrogen may occur, such as valves, flanges, and seals. Bolted flange connections of hydrogen piping should be avoided where welded connections are feasible. (9.5.1)

17.9.5.2 The pipes should be mechanically protected. (9.5.2)

17.9.5.3 Low pressure secondary enclosures should be provided with an inert gas system, or alternatively fitted with a redundant mechanically ventilation system with sufficient capacity based on results from CFD analysis. (9.5.3)

17.9.5.4 Compressed hydrogen high-pressure gas piping systems should have sufficient constructive and fatigue strength. This should be confirmed by carrying out stress and fatigue analysis and taking into account:

.1 stresses due to the weight of the piping system
.2 acceleration loads that give a stress equal to more than 20% of the stress from the internal pressure in the pipe.
.3 internal pressure and loads induced by hog and sag of the ship. (9.5.4)

17.9.5.5 Filters (9.5.5)

17.9.5.5.1 Appropriate means, e.g. filtering, should be provided in fuel piping systems to remove impure substances condensed at low temperature. (9.5.5.1)

17.9.5.5.2 Filters are useful for reducing hazards associated with contamination, especially from solid particles, and in liquid hydrogen systems from solid particles that could include oxygen, but they are also an obstacle for the flow. The primary purpose of a filter is to collect impurities in the hydrogen system. (9.5.5.2)

17.9.5.5.3 The following recommendations concerning filters should be considered:

.1 Filters should be accessible and capable of being isolated for cleaning.
.2 Filters should not be cleaned by back-flushing through the system.
.3 Filters should be cleaned or replaced periodically or whenever the pressure drop across the filter reaches a specified value.
.4 The quantity and location of filters should be determined as required to minimize impurities in the system. (9.5.5.3)

17.9.6 ***Valve arrangements*** (9.6)

17.9.6.1 As valves are prone to leaks, valves in hydrogen piping systems should be limited to the minimum but should be sufficient to provide the minimum safety functions. (9.6.1)

17.9.6.2 Valves in the fuel piping system, from the bunkering station to the consumers, should normally be automatic and remotely operated to minimize personnel exposure, and the valves should always be easily accessible for inspection and maintenance. This recommendation does not apply to normally closed and locked valves not operated during normal service. (9.6.2)

17.9.6.3 Tank valves should be automatically or manually operated in line with the safety principles laid out in 9.4.1 (13.1). (9.6.3)

17.9.6.4 All valves in the hydrogen piping system are recommended to be pneumatic or hydraulic controlled in order to provide inherently safe design with respect to ignition control. (9.6.4)

17.9.6.5 The main fuel supply line to each gas consumer or set of consumers should be equipped with a remotely operated stop valve and an automatically operated master gas fuel valve coupled in series. The valves should be situated in the part of the piping that is outside the machinery spaces containing gas consumers and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve should automatically cut off the gas supply when activated by the safety system laid out in 17.13.1. (9.6.5)

17.9.6.6 The gas supply line to each consumer should be provided with double-block-and-bleed valves. These valves should be arranged for automatic shutdown as given in section 17.13.1, and for normal stop and shutdown of the fuel cells or engines. The master gas fuel valve may perform this function. An alarm for faulty operation of the valves should be provided. In this context block valves open and bleed valve closed is an alarm condition. Similarly, gas consumers stopped and block valves open is an alarm condition. There should be one remotely operated shutdown valve in the gas supply line to each gas consumer upstream of the double block and bleed valves to assure safe isolation during maintenance on the fuel cell module. (9.6.6)

17.9.7 ***Expansion bellows*** (9.7)

17.9.7.1 The use of expansion bellows is subject to approval by the administration, and if fitted, should be certified by RO. (9.7.1)

17.9.8 ***Overpressure protection of fuel tanks and piping systems*** (9.8)

17.9.8.1 Design principles (9.8.1)

17.9.8.1.1 Hydrogen overpressure protection and vent systems should be engineered by personnel with sound experience with the design of gas venting systems. (9.8.1.1)

17.9.8.1.2 The design loads and temperature effects used for the design of the venting systems and vent mast should be documented in the pipe stress analysis. See documentation list in Annex A. (9.8.1.2)

17.9.8.1.3 The vent mast should have a design pressure not less than 20 bar. (9.8.1.3)

17.9.8.1.4 Pressure relief systems should be suitably designed and constructed to prevent blockage due to formation of water or ice. (9.8.1.4)

17.9.8.2 Pressure relief valves (PRVs) (9.8.2.)

17.9.8.2.1 Relief valve sizing should be undertaken for the most onerous scenario. Whether this scenario is brought into existence due to fire or by loss of vacuum from the overall insulation system should be assessed and the resulting magnitude of the heat flux on the containment system considered in each case. (9.8.2.1)

17.9.8.2.2 Pressure relief valves for hydrogen service should be certified irrespective of size and design conditions. (9.8.2.2)

17.9.8.2.3 The PRV design should be carried out according to most severe service conditions (design pressure, design temperature, optional additional loads) applicable for the H_2 service conditions under each specific traceable marking number. The design should be carried out under observation of the maximum flow capacity expected for specific PRV operating characteristics. (9.8.2.3)

17.9.8.2.4 For each Pressure Relief Valve type to be intended for hydrogen use a data sheet available covering all should be available with the specified service and design conditions under a relevant TAG number. (9.8.2.4)

17.9.8.2.5 PRVs scheduled for installation in hydrogen systems are to be classed within Pipe Class I / Pressure Vessel Class I. Design of Pressure Relief Valves for H_2 service should be carried out according to an international recognized standard. (9.8.2.5)

17.9.8.2.6 Capacity sizing for Pressure Relief Valves intended for installations on H_2 fuel systems should be carried out according to IGC 8.4. For hydrogen the relevant physical, chemical and thermodynamic properties, such as molecular mass, latent heat, ratio of specific heats at relieving conditions, etc., are to be observed. (9.8.2.6)

17.9.8.3 Vent mast (9.8.3.)

17.9.8.3.1 The vent mast should be located away from air intakes, outlets or openings to accommodation spaces, service spaces, and control stations, and should not direct the releases into the defined non-hazardous area. Case-by-case gas dispersion assessments/simulations are needed in order to be able to adequately size and determine the location of the vent mast. The vent mast height should be sufficient to prevent thermal radiation from affecting the personnel and structures on board. (9.8.3.1)

17.9.8.3.2 Condensate drains are required on all hydrogen vent masts subject to cold vapours. Drip trays made of low-temperature materials may be permitted to prevent brittle fracture caused by liquid air formation. (9.8.3.2)

17.9.8.3.3 Due consideration should be given to the risks associated with highly enriched oxygen formation. (9.8.3.3)

17.9.8.3.4 Flammable concentrations may lead to DDT in vent masts of sufficient length. The ratio diameter/length should be designed to prevent that occurrence by design. (9.8.3.4)

17.9.8.3.5 It is also recommended that the vent masts are arranged with inert gas system for purging of air when hydrogen is not flowing. Molecular seals to prevent air ingress at the vent mast outlet should be considered. (9.8.3.5)

17.9.8.3.6 Vent mats should be grounded to prevent built up of static electricity. (9.8.3.6)

17.9.8.3.7 Appropriate measures should be provided to prevent vents becoming blocked by accumulations of ice formed from moisture in the air. (9.8.3.7)

17.9.8.3.8 The vent system should be designed in such a way that no liquid hydrogen is vented. (9.8.3.8)

17.9.8.4 Flaring and considerations to vent mast ignition (9.8.4)

17.9.8.4.1 It is not recommended to use flaring for venting hydrogen fuel systems onboard vessels. Due to hydrogen's high reactivity and wide flammability flaring poses more hazards than benefits when using hydrogen as ship fuel.

17.9.8.4.2 The ignition of flammable gases and combustion events at the vent mast should be prevented by design.

17.9.8.5 Pressure relief and venting systems for liquid hydrogen systems (9.8.5)

17.9.8.5.1 Pressure relief valves and venting systems should be dimensioned considering the worst-case scenario relevant for sizing the pressure relief systems. For instance, it should be considered that loss of vacuum would occur as a consequence of the fire around a tank.

17.9.8.5.2 The safety relief valves, vent pipes and the vent mast should be designed and installed to minimize moisture accumulation and ice build-up from atmospheric condensation.

17.9.8.5.3 If rupture disks are used to protect secondary enclosures, the devices should be used in parallel with a pressure-relief valve as a fail-safe path for over-pressurization or in series (upstream) when subsequent ingress of air is unacceptable.

17.9.8.6 Pressure relief and venting systems for hydrogen systems (9.8.6)

17.9.8.6.1 Means should be provided to prevent the fuel tanks from rupturing due to fire exposure. An automatic pressure relief system should be fitted for that purpose. The installed overpressure protection for fire exposure should be reliable and able to keep the exposed equipment below the rupture stress at all times. The fire exposure criteria used as a basis for design should consider project-specific fire risks in addition to the minimum standard fire exposure conditions provided for dimensioning pressure relive valves in 6.7 (IGF Code 6.7). It should also consider the recommendations given in *API Std 521 Pressure-relieving and depressuring Systems*.

17.9.8.6.2 High-pressure gas should be prevented from reaching low-pressure segments. Pressure relief systems or high-integrity pressure protection systems should be considered as necessary. Uncontrollable high-pressure hydrogen leakages should be prevented by design. A single leak should not lead the hydrogen fuel installation to an unsafe scenario. Inherently safe means of disposal should be fitted.

17.9.8.6.3 Blowdown of the gas to a safe location can be an adequate safety measure to ensure the safe disposal of gas and reduce the duration of the leak. If blowdown systems are used, they should, as a minimum, be designed in accordance with the recommendations given in API Std 521 *Pressure-relieving and Depressuring Systems*.

17.9.8.6.4 In multi-tank installations, it should be possible to determine which fuel tank is leaking based on input from the safety systems. It should be possible to safely empty a leaking tank by remote control to prevent escalation. Consideration is to be given to the effects of backpressure created from high-pressure releases on the outlet of the lower pressure relief valves affecting their setpoint.

17.9.8.6.5 A dedicated vent mast for vent and disposal from high pressure compressed hydrogen fuel should be arranged.

17.9.9 ***Inert and vacuum systems*** (9.9)

17.9.9.1 General (9.9.1)

17.9.9.1.1 Spaces containing inert gas installations should as a minimum comply with the requirements given in by RO unless specified in this section.

17.9.9.1.2 An arrangement for purging fuel bunkering lines and hydrogen piping systems should be provided.

17.9.9.1.3 In order to ensure proper purging of the hydrogen pipes to avoid flammable mixtures, including the components in system, it is recommended that a minimum required flow rate and purging speed are evaluated at which pipes and components are sufficiently purged.

17.9.9.1.4 For safety, due consideration should be given to temperature and boiling points of the inert gases. Residual pockets of hydrogen or the purge gas will remain in the enclosure if the purging rate, duration, or extent of mixing is too low. Therefore, reliable gas concentration measurements should be obtained at a number of different locations within the system for suitable purges. Temperature should also be measured at a number of locations. Oxidizing agents may exist in a hydrogen containing equipment, specifically: air, cold box atmospheres containing air diluted with nitrogen, or oxygen-enriched air that can be condensed on process pipe work within the cold box in special circumstances.

17.9.9.1.5 There are special measures that may need to be put in place in order to mitigate the hazards, e.g. air should be eliminated by nitrogen purge prior to introduction of hydrogen into cargo piping or processing equipment. Nitrogen should then be eliminated by hydrogen purge, where there is a possibility of its solidification in the subsequent process.

17.9.9.1.6 Hydrogen pipelines and components should be purged with an inert gas before and after using hydrogen in the pipelines and components. Inert gas is to be used to remove moisture and air prior to introducing hydrogen into the piping system. In addition, hydrogen should be purged from the piping system with an inert gas before opening the system for maintenance.

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

17.9.9.1.8 The inert gas system should be designed so that each space being inerted can be isolated and the necessary arrangements should be provided for controlling the pressure in these spaces.

17.9.9.1.9 The hold spaces used for storage of compressed gas bottles or liquid hydrogen need to be continuously inerted to prevent an explosive atmosphere in case of a leakage.

17.9.9.1.10 The inert gas system should be protected against contamination with hydrogen.

17.9.9.1.11 It is recommended that secondary barriers in gaseous H_2 pipelines both in liquefied liquid hydrogen and compressed hydrogen systems are arranged with a nitrogen inert gas system. If the secondary barriers in gaseous H_2 pipelines are mechanically ventilated, the recommendations given in section 10 should be considered.

17.9.9.2 Liquid hydrogen inerting systems (9.9.2)

17.9.9.2.1 Liquid helium may be used as an inert gas for purging and for pre-cooling of the bunkering line and components due to its low boiling point.

17.9.9.2.2 The liquid hydrogen secondary barrier in fuel bunkering lines and supply lines should be inerted with helium or vacuum insulation.

17.9.9.2.3 The primary gaseous supply lines and components should be arranged for purging with nitrogen inert gas.

17.9.9.3 Compressed hydrogen inerting systems (9.9.3)

In high-pressure H_2 pipelines the supply lines and components should be arranged for purging with nitrogen inert gas. In addition, the secondary barrier(s) should be supplied with a nitrogen inert gas.

17.9.9.4 Inert gas production and storage on board (9.9.4)

If inert gas generators are provided, they should be capable of producing inert gas with oxygen content equal to or less than 3% (Ref. NFPA 22, Annex L, L.2.2.3.2, 2020 Ed.) by volume for nitrogen and x% for helium. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5% oxygen content by volume.

17.9.10 ***Fuel bunkering piping systems*** (9.10)

17.9.10.1 General (9.10.1)

17.9.10.1.1 The fuel bunkering system should as a minimum fulfil the requirements given in (the IGF Code) 8.1, 8.2, 8.3, 8.4 and 8.5, unless specified in this section.

17.9.10.1.2 In general, the bunkering system should be arranged so that no gas or liquid will be discharged to air during filling of the fuel tanks.

17.9.10.1.3 A bunkering operational procedure should be made and kept onboard.

17.9.10.2 Fuel bunkering with fixed liquid hydrogen systems (9.10.2)

17.9.10.2.1 Due to the cryogenic exposure to the adjacent hull structure in case of a liquid hydrogen leakage, materials suitable to low temperature should be used in way of the hull under shore connections.

17.9.10.2.2 Water distribution protection system is advised not to be fitted in way of the hull under the shore connections.

17.9.10.3 Fuel bunkering with fixed H_2 systems (9.10.3)

17.9.10.3.1 Safe operating pressure should be maintained in the gas supply lines after the bunkering manifold.

17.9.10.3.2 Redundant pressure reduction valve should be fitted immediately after the bunkering manifold where the compressed hydrogen gas is reduced to low pressures.

17.9.10.4 Containerized swappable compressed hydrogen solutions (9.10.4)

17.9.10.4.1 Containerized swappable compressed hydrogen systems should have equivalent safety, be certified and approved as the fixed fuel supply solutions specified in 7.8.1.

17.9.10.4.2 Redundant pressure reduction valve should be fitted, as close as possible to the tank's ESD valve, on the common supply line header on each container, in order to provide safe operating pressure in the gas supply line.

17.9.10.4.3 If flexible hoses with couplings are applied as gas supply lines between the bunkering manifold and the container(s) they should be type-approved for the intended medium and service, and arranged for automatic purging with inert gas. These hoses should be provided with secondary enclosure inerted with nitrogen.

17.9.10.4.4 Containers should be regarded as tank hold spaces with regard to recommendations related to explosive atmospheres.

17.9.11 Fuel supply piping systems

17.9.11.1 The welded joints of fuel pipes are to be of full penetration as far as practicable. If a hydrogen supply pipe with a diameter of 25mm or less cannot be fully welded, the welded joints of full penetration type are to be minimized as far as practicable and located in the gas valve unit space. (9.11.1)

17.9.11.2 All components in fuel piping are to be made of materials suitable for their intended use and with corrosion resistance, and all tubes in fuel piping are to be seamless steel pipe. (9.11.2)

17.9.11.3 Arrangements of fuel supply piping systems (9.11.3)

17.9.11.3.1 A manually operated stop valve and a tank master valve in series, or a combined manually operated and master valve are to be fitted in every gas supply outlet of the tank, and to be located close to the tank as far as possible. (9.11.3.1)

17.9.11.3.2 The main gas supply line to each consumer or set of consumers is to be equipped with a manually operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined manually and automatically operated valve. The master gas fuel valve is to be situated outside the machinery space. (9.11.3.2)

17.9.11.3.3 The surface temperature of fuel piping in the machinery space is not to exceed the 80% of auto-ignition temperature of the fuel used. (9.11.3.3)

17.9.11.3.4 Fuel piping are not to be led directly through machinery spaces other than the spaces for hydrogen consumers, accommodation spaces, service spaces, electrical equipment rooms or control stations and their air inlets. Fuel piping passing through enclosed spaces other than these spaces are to be double walled. (9.11.3.4)

17.9.11.3.5 As far as practicable, hydrogen lines are to be arranged far apart from hot surfaces, electrical installations or other positions where an arc or sources of ignition may occur. (9.11.3.5)

17.9.11.3.6 Metal parts supporting and securing low temperature pipes are not to be in direct contact with the pipes. (9.11.3.6)

17.9.11.3.7 Rigid piping is to be arranged properly and in order, without any collision and friction with adjacent parts; Pipe supports and protective pads are to be vibration-resistant and eliminate the impact of expansion and contraction. The pipe's radius of curvature of the centre line is to be no less than three times the outer diameter of the pipe when bending. The middle part of a pipe fixed at both ends is to be properly bent with supports having a spacing of not more than 1 m. (9.11.3.7)

17.9.11.3.8 Fuel valves which can only be closed manually are to be ensured to easily operate and be readily accessible, unless they can be closed remotely or automatically so as to cut off the fuel supply to pipes in time. (9.11.3.8)

17.9.11.3.9 The pipes between hydrogen cylinders and consumers are to be provided with valves and equipment based on the consumer's characteristics and the system design, where necessary, such as flow-limiting valves, high pressure valves, fire valves and regulator valves. (9.9.3.9)

17.10 Power generation including propulsion and other fuel consumers (10)

17.10.1 *Goal* (10.1)

17.10.1.1 The goal of this section is to provide safe and reliable delivery of mechanical, electrical or thermal energy. (10.1.1)

17.10.2 *Functional requirements* (10.2)

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

.1 the exhaust systems should be configured to prevent any accumulation of un-burnt gaseous fuel;

.2 unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture should be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

.3 the explosion venting should be led away from where personnel may normally be present; and

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

17.10.3 *Regulations for internal combustion engines of piston type* (10.3)

17.10.3.1 General (10.3.1)

17.10.3.1.1 The exhaust system should 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 unburnt gas in the system. (10.3.1.1)

The exhaust system should be equipped with explosion relief systems unless designed to accommodate the worst case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation of the potential for unburnt gas in the exhaust system is to be undertaken covering the complete system from the cylinders up to the open end. This detailed evaluation should be reflected in the safety concept of the engine. (10.3.1.1.1)

17.10.3.1.2 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 should be carried out and reflected in the safety concept of the engine. (10.3.1.2)

17.10.3.1.3 Each engine other than two-stroke crosshead diesel engines should be fitted with vent systems independent of other engines for crankcases and sumps. (10.3.1.3)

17.10.3.1.4 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means should be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the atmosphere. (10.3.1.4)

17.10.3.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit should be verified. (10.3.1.5)

17.10.3.1.6 A means should be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations. (10.3.1.6)

17.10.3.1.7 For engines starting on fuels covered by this *Publication* (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 should be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system should be provided. (10.3.1.7)

17.10.3.2 Regulations for dual fuel engines (10.3.2)

17.10.3.2.1 In case of shut-off of the gas fuel supply, the engines should be capable of continuous operation by oil fuel only without interruption. (10.3.2.1)

17.10.3.2.2 An automatic system should 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 should be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine should automatically change to oil fuel mode. Manual activation of gas system shutdown should always be possible. (10.3.2.2)

17.10.3.2.3 In case of a normal stop or an emergency shutdown, the gas fuel supply should be shut off not later than the ignition source. It should 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. (10.3.2.3)

17.10.3.3 Regulations for gas-only engines (10.3.3)

In case of a normal stop or an emergency shutdown, the gas fuel supply should be shut off not later than the ignition source. It should 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.

17.10.3.4 Regulations for multi-fuel engines (10.3.4)

17.10.3.4.1 In case of shut-off of one fuel supply, the engines should be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power. (10.3.4.1)

17.10.3.4.2 An automatic system should be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability should be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine should automatically change to an alternative fuel mode. Manual activation should always be possible. (10.3.4.2)

17.11 Fire safety (11)

17.11.1 *Goal* (11.1)

The goal of this Chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of hydrogen as ship fuel.

17.11.2 *Functional requirements* (11.2)

This Chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

17.11.3 *Fire protection* (11.3)

17.11.3.1 Hydrogen fuel tanks:

.1 Any boundary of accommodation spaces, service spaces, control stations, machinery spaces, and escape routes facing fuel tanks on open deck are to have a fire integrity class of A-60. These class divisions are to extend up to the underside of the deck of the navigation bridge or up to the true height of the bulkhead.

.2 Isolation is to be provided between the fuel storage hold space and machinery spaces of category A or other high fire risk spaces is to be done by a cofferdam of at least 900 mm with insulation of A-60 class. In determining the insulation of the fuel storage hold space from other spaces with lower fire risks, the fuel storage hold space is to be regarded as a machinery spaces of category A. The boundary between fuel storage hold spaces is to be either a cofferdam of at least 900 mm or A-60 class division. (11.3.1)

17.11.3.2 Bunkering stations:

.1 The boundaries of a machinery spaces of category A, accommodation space, control station and space of greater fire risk facing the bunkering station are to be insulation of A-60 class, but the boundaries of a liquid tank, void, auxiliary machinery space and sanitary and other similar space may be reduced to A-0 class. (11.1.2)

17.11.4 *Fire-extinguishing* (11.4)

17.11.4.1 Spaces for hydrogen consumers, fuel storage hold spaces and fuel preparation rooms are to be fitted with a suitable Fixed Fire-Extinguishing System (FFES) required in the International Code for Fire Safety Systems (FSS Code) and appropriate to the fuel chemistry used in those spaces. The FFES is to adequately consider the potential fire loads involved. (11.4.1)

17.11.4.2 Where hydrogen is used as the primary fuel, the extinguishing media used in the spaces mentioned in 8.2.1 is to be dry powder or carbon dioxide. (11.4.2)

17.11.4.3 The hydrogen bunkering station is to be fitted with a fixed dry powder fire-extinguishing system which is to cover all possible leakage points. The capacity is to be at least 3.5 kg/s for a minimum of 45 s. The system is to be arranged for easy manual release from a safe location outside the protected. (11.4.3)

17.11.5 *Fire detection and fire alarm systems* (11.5)

17.11.5.1 Fuel storage hold spaces (including ventilated ducts if located under the deck), fuel cell spaces and other spaces where flammable gases may occur are to be provided with a fixed fire-fighting system required in FSS Code. (11.5.1)

17.11.5.2 Where hydrogen is used, smoke detectors and thermal detectors are to be provided. Arrangements are provided to rapidly detect leakages of other gas reformed fuel. (11.5.2)

17.11.5.3 If the fixed fire detection and fire alarm system does not have the capability to remotely identify each detector individually, each detector is to be supplied from separate circuits. (11.5.3)

17.12 Explosion prevention (12)

17.12.1 *Goal* (12.1)

The goal of this Chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.

17.12.2 *Functional requirements* (12.2)

This Chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:

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

.1 reducing number of sources of ignition; and

.2 reducing the probability of formation of ignitable mixtures.

17.12.3 *General* (12.3)

17.12.3.1 Explosion risks described in the Marhysafe handbook, particularly in 17.8.3.1, are to be considered. (12.3.1)

17.12.3.2 An explosion risk analysis (ERA) is required to evaluate the risks of explosions in detail. The ERA should be carried out early in the design phase. Several mitigating barriers can be applied as a result of the study or as part of the case-by-case safety philosophy. Those barriers may include purpose-built light and fast-acting explosion panels, additional reduction of potential oxidant concentrations and explosion suppression methods. (12.3.2)

17.13 Ventilation (13)

17.13.1 *Goal* (13.1)

The goal of this Chapter is to provide for the ventilation required for safe operation of hydrogen fuelled machinery and equipment

17.13.2 *Functional requirements* (13.2)

This Chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

17.13.2.1 Unless expressly provided otherwise, the requirements of 13.3.1, 13.3.3, 13.3.4, 13.3.9 and 13.3.10 of this *Publication* (the IGF Code part A-1) should apply to ships using hydrogen as fuel. (13.2.1)

17.13.3 *General provisions* (13.3)

17.13.3.1 Air inlets for non-hazardous enclosed spaces are to 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 is to have over-pressure relative to this space, except that its mechanical integrity and air tightness ensure that gases do not penetrate into the space. (13.3.1)

17.13.3.2 Electric fan motors are not to be located in ventilation ducts for mechanical spaces unless the motor is certified for hydrogen. (13.3.2)

17.13.3.3 Ventilation systems are to be capable of being controlled at a position outside of the ventilated space. The space is to be so arranged that it can be ventilated prior to personnel entry and operation of equipment. Warning signs are to be placed outside of the space for alerting personnel to start the ventilation system prior to entry. The space is to be monitored for flammable gas. (13.3.3)

17.13.3.4 Suitable protective screens of not more than 13 mm square mesh are to be fitted on vent outlets of hazardous spaces. (13.3.4)

17.13.3.5 Air outlets from non-hazardous spaces are to be located outside hazardous areas. (13.3.5)

17.13.3.6 Air outlets from gas hazardous spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space. (13.3.6)

17.13.3.7 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. (13.3.7)

17.13.3.8 For a space having a hazard level depending on ventilation system:

.1 During initial start-up or after loss of overpressure ventilation, and before energizing any electrical installations not certified safe for the space in the absence of pressurization, it is to proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous. A warning sign is to be posted near the console;

.2 Operation of the overpressure ventilation is to be monitored; and

.3 at a failure of ventilation system:

- **.1** An audible and visual alarm being given; and
- **.2** Ventilation is to be immediately restored. (13.3.7)

17.13.4 ***Fuel tank connection spaces*** (13.4)

17.13.4.1 Fuel tank connection spaces are to be provided with a mechanical extraction ventilation system of the extraction type, with a ventilating capacity of 30 air changes per hour. (13.4.1)

17.13.4.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable. (13.4.2)

17.13.4.3 If tank connections are located in the fuel tank space, it is also to comply with the requirements of 7.2.1 and 7.2.2. (13.4.3)

17.13.5 *Fuel preparation rooms* (13.5)

17.13.5.1 Fuel preparation rooms are to be fitted with an effective mechanical forced ventilation system of extraction type. During normal operations the ventilation capacity is to provide at least 30 air changes per hour. (13.5.1)

17.13.5.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable. (13.5.2)

17.13.5.3 Ventilation systems for fuel preparation rooms and other fuel handling spaces are to be in operation when pumps or other fuel treatment equipment are working. (13.5.3)

17.13.6 *Bunkering stations* (13.6)

17.13.6.1 Bunkering stations that are located in an enclosed space are to be provided with an efficient mechanical ventilation system to ensure at least 30 air changes per hour. (13.6.1)

17.13.6.2 Bunkering stations that are located in a semi-enclosed space are to be provided with a mechanical ventilation system based on the risk assessment conclusion required in 5.1.1. (13.6.2)

17.14 Electrical Installations (14)

17.14.1 *Goal* (14.1)

The goal of this Chapter is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

17.14.2 *Functional requirements* (14.2)

This Chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

17.14.3 *General Provisions* (14.3)

17.14.3.1 Electrical equipment and wiring are in general not to be installed in hazardous areas. If this is impracticable, they are to comply with the provisions of this section. (14.3.1)

17.14.3.2 Where electrical equipment is installed in hazardous areas, it is to be of a certified safe type appropriate for the resulting area classification. Refer to IEC 60079-10-1. (14.3.2)

17.14.3.3 Equipment groups and temperature classes are to be determined as follows according to the categories of the flammable gas which may occur and accumulate in a hazardous area:

.1 Hydrogen, not less than IIC, T1. (14.3.3)

17.14.3.4 Equipment installed in hazardous areas is to have an explosion-proof certificate issued by an explosion prevention authority. Means for gas detecting and automatically isolating non-certified safe type electrical equipment is not to be used instead of the use of certified safe type electrical equipment. (14.3.4)

17.14.4 ***Hazardous area classification*** (14.4)

17.14.4.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1and 2 according to 6.2.3. If the provisions in 6.2.3 are considered not applying to certain circumstances, the Administration may allow the use of IEC 60079-10 for hazardous area classification. (14.4.1)

17.14.4.2 The classification of ventilation duct areas is to be the same as that of ventilated spaces. (14.4.2)

17.14.4.3 Hazardous areas

.1 Hazardous area zone 0

This zone includes, but is not limited to the interiors of fuel tanks and reformers, any pipework for pressure- relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

.2 Hazardous area zone 1

These include, but are not limited to:

.1 tank connection spaces, fuel storage hold spaces and inter-barrier spaces;

.2 fuel cell spaces;

.3 fuel preparation rooms

.4 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange and other reformed fuel source of release, fuel preparation room ventilation outlets, zone 1 ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.5 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel cell space entrance, fuel cell space ventilation inlets, fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

.6 spaces on the open deck within drip trays for bunker manifold valve and 3 m beyond these, up to a height of 2.4 m above the drip tray;

.7 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. double walled pipe around fuel pipes, semi-enclosed bunkering stations;

.8 a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

.9 except for compressed hydrogen cylinder tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.

.3 Hazardous area zone 2

These include, but are not limited to:

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

.2 space containing bolted hatch to tank connection space. (14.4.3)

17.15 Control, Monitoring and Safety Systems (15)

17.15.1 *Goal* (15.1)

The goal of this Chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other chapters of this *Publication* (Code).

17.15.2 *Functional requirements* (15.2)

This Chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular, the following apply:

.1 the control, monitoring and safety systems of the hydrogen installation shall be so arranged that the remaining power for propulsion and power generation is in accordance with 9.3.1 in the event of single failure;

.2 a hydrogen safety system shall be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention;

.3 for ESD protected machinery configurations the safety system shall shutdown gas supply upon hydrogen leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

.4 the safety functions shall be arranged in a dedicated hydrogen safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

.5 the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

.6 where two or more hydrogen supply systems are required to meet the regulations, each system shall be fitted with its own set of independent hydrogen control and hydrogen safety systems.

17.15.3 *General arrangement* (15.3)

17.15.3.1 The control, monitoring and safety systems needed to provide a safe and reliable operation of a hydrogen installation should be based on the same design principles applied in LNG gas fuelled installation; however, extended and adapted with necessary capabilities to cover the additional risk associated with the use of hydrogen gas. (15.3.1)

17.15.3.2 For gas fuelled installations, multiple safety scenarios will cause shutdown of the gas supply and isolation of ignition sources, i.e. fail safe for such arrangements will normally lead to loss of the function powered by the gas. Machinery arrangement driven by gas-fuelled only therefore need to be arranged with duplication and segregation to ensure that the propulsion function may be maintained – or readily restored – even after any failure or safety action shutting down one of the units. This general design philosophy should also be applied to the control, monitoring and safety system, and the overall arrangement of the control, monitoring and safety systems should for each of the duplicated hydrogen supply systems consist of:

.1 a dedicated system handling the normal control and monitoring of the hydrogen plant; and

.2 a redundant safety system handling the safety of the hydrogen installation. (15.3.1)

17.15.3.3 It is a well-established design principle that safety systems should be independent of the control and monitoring systems, thereby constituting independent barriers and fault tolerance to prevent a failure or process upset to develop into a hazard. The safety system should for each of the duplicated hydrogen supply systems be arranged with redundancy to ensure that even after a failure within the safety system, which may lead to shut down of the gas supply, the safety system remains operational to provide the safety functions including gas detection and alarming also for the gas supply line exposed to the failure. (15.3.3)

17.15.3.4 The hydrogen supply may be used as fuel in different system arrangements, e.g. in fuel cells or potentially directly in combustion engines. Depending on the "end use", the arrangement of the control, monitoring and safety systems described above may be combined with the corresponding functions associated with the fuel cell compartment/engine compartment. (15.3.4)

17.15.3.5 For dual fuel arrangements, i.e. where hydrogen is not the only source of energy for the essential ship systems, the same principles as for a dual fuel LNG installation should apply. The general assumption is then that in case the gas fuel supply fails or is shut down, change over and continued operation by use of the other fuel will ensure the required availability of the propulsion system. For hydrogen fuel arrangements, it should however be evaluated if continued operation on the alternative fuel is safe if the cause of the fuel changeover was related to gas leak and subsequent risk of explosion. (15.3.5)

17.15.3.6 Suitable instrumentation devices are to be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering. (15.3.6)

17.15.3.7 The safety system is to be independent of the control and monitoring system. (15.3.7)

17.15.4 ***Gas and fire detection*** (15.4)

17.15.4.1 The inherent properties of hydrogen gas and associated risks necessitate early and accurate continuous monitoring of gas leakage or fire detection, degradation, or loss of safety barriers (e.g. ventilation) – and activation of appropriate safety actions (shutdown, isolation of ignition sources). (15.4.1)

17.15.4.2 The detection principles for gas should be based on diversity, i.e., a combination of different detection principles should be applied to ensure adequate coverage for the variety of leakage scenarios in the relevant spaces. This may involve point detectors, line detectors possibly supplemented by effective alternative methods like e.g. acoustic detection. The LFL (lower flammable limit) for hydrogen gas concentration is very low, and the detecting principles should ensure early warning at very low levels of concentration, see 8 and 7.1. Voting principles should be considered to balance the need for early detection versus the risk for spurious shutdowns. (15.4.2)

17.15.4.3 For fire detection the same principles should basically apply; different detection principles should be utilized to provide early detection of fire (flame/smoke/heat) and potentially alternative principles. (15.4.3)

17.15.4.4 The physical arrangement of the compartments, spaces and areas that may be exposed to gas leakage or fire should be duly analysed and detectors based on the different detection principles should be applied to provide early and accurate coverage. (15.4.4)

17.15.4.5 Due consideration should be given to appropriate safety measures to prevent formation of explosive mixture in the case of a leakage of hydrogen, including:

.1 installation of hydrogen detectors in order to detect a possible ground-level travel of low temperature hydrogen gas, and at high points in spaces where warm hydrogen gas can be trapped; and

.2 application of "best practice" for land-based liquid hydrogen storage taking into account appropriate guidance such as "Cryogenics Safety Manual – Fourth Edition (1998)". (15.4.5)

17.15.4.6 Detection of gas leakage or loss/degraded ventilation should cause immediate shutdown of hydrogen flow and isolation of ignition sources in the affected areas. In order to enable continued operation of the other propulsion line and associated hydrogen supply system after a shut-down, the potential spaces where hydrogen gas may propagate to the operating machinery spaces should be duly monitored. (15.4.6)

17.15.4.7 For LNG fuelled arrangements, fire detection does not trigger any automatic safety action; a fire will be alarmed, and it is up to the crew to decide on necessary actions (e.g. Manual shutdown and isolation of ignition sources and initiation of possible fire-fighting measures). For hydrogen installations, the risks associated with hydrogen gas leakage presumably necessitates automatic action upon fire detection – with similar measures as for gas detection, i.e., shutdown of gas supply/flow and isolation of ignition sources. Fire detection in the spaces and areas exposed to hydrogen should be part of the ship's general fire detection system. However, due to the increased risks associated with hydrogen leakage, the fire detection system should be arranged with redundancy to ensure that no single failure in the fire detection system impairs the fire detection capabilities including subsequent safety actions and alarming. (15.4.7)

17.15.4.8 Fire detectors for detecting hydrogen fire should be selected after due deliberation, taking into account the features of hydrogen fire, to the satisfaction of the administration. Due consideration should be given to the invisible nature of hydrogen fire. (15.4.8)

17.15.4.9 The alarms associated with gas and fire detection should be routed to both the bridge and engine control room and locally in relevant spaces. (15.4.9)

17.15.4.10 Manual shutdown buttons should be provided, i.e. at the bridge, engine control room and the bunkering station. (15.4.10)

17.15.5 ***Fuel supply system monitoring*** (15.5)

17.15.5.1 An overpressure protection device is to be provided for a fuel supply system, giving an audible and visual alarm at an overpressure. (15.5.1)

17.15.5.2 The purity of reforming fuel gas is to be monitored for fuel cells sensitive to gas concentration, giving an audible and visual alarm in exceeding the limits. (15.5.2)

17.15.5.3 The following items are to be monitored for the equipment associated to the fuel supply system, and an audible and visual alarm is to be given in exceeding the limits:

.1 High pressure at the outlet from the fuel heat exchanger;

.2 Hight pressure at the outlet from the fuel compressor;

.3 Low pressure at the inlet to the fuel compressor;

.4 High pressure and low pressure at the inlet to the fuel compressor;

.5 Low pressure and high temperature of the compressor oil; and

.6 Abnormal shutdown of the master fuel valve. (15.5.3)

17.15.6 ***Liquid fuel monitoring*** (15.6)

17.15.6.1 The space where liquid fuel leakage may occur is to be provided with a rapid detector for liquid fuel. (15.6.1)

17.15.7 ***Ventilation monitoring*** (15.7)

17.15.7.1 Any loss of the required ventilating capacity is to give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre. (15.7.1)

GENERAL INFORMATION – HYDROGEN PROPERTIES

This Table comes from the *Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk* resolution MSC.420(97) adopted on 25 November 2016.

Comparison of physical properties of Hydrogen and Methane

	HYDROGEN	**METHANE**	References
Boiling temperature (K)*	20.3	111.6	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex A, Table A.3
Liquid density (kg/m^3)*	70.8	422.5	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex A, Table A.3
Gas density (kg/m^3)** (Air: 1.198)	0.084	0.668	National Institute of Standards and Technology (NIST) RefProp database
Viscosity (g/cm s × 10^{-6})			
Gas	8.8	10.91	National Institute of Standards and Technology (NIST) RefProp database
Liquid	13.49	116.79	National Institute of Standards and Technology (NIST) RefProp database
Flame temperature in air (°C)	2396	2230	Calculated using Cantera and GRI 3.0 mechanism
Maximum burning velocity (m/s)	3.15	0.385	Calculated using Cantera and GRI 3.0 mechanism
Heat of vapourization (J/g)*	454.6	510.4	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex A, Table A.3
Lower flammability limit (% vol. fraction)***	4.0	5.3	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex B, Table B.2
Upper flammability limit (% vol. fraction)***	77.0	17.0	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex B, Table B.2
Minimum ignition energy (mJ)***	0.017	0.274	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex B, Table B.2
Auto-ignition temperature (K)***	858	810	ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex B, Table B.2
Toxicity	Non	Non	
Temperature at critical point (K)	33.19****	190.55	**Hydrogen**: ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex A, Table A.1 **Methane**: The Japan Society of Mechanical Engineers, Data Book, Thermophysical Properties of Fluids (1983)
Absolute pressure at critical point (kPa)	1315****	4595	**Hydrogen**: ISO/TR 15916:2015, *Basic consideration for the safety of hydrogen systems*, Annex A, Table A.1 **Methane**: The Japan Society of Mechanical Engineers, Data Book, Thermophysical Properties of Fluids (1983)

Remarks:

* At their normal boiling points for comparison purpose.
** At normal temperature and pressure.
*** Ignition and combustion properties for air mixtures at 25°C and 101.3 kPa absolute pressure.
**** Normal Hydrogen.

ANNEX 1
STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF FUEL CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION (IGC CODE Annex)

1 GENERAL

1.1 The purpose of this standard is to provide procedures and relevant design parameters of limit state design of fuel containment systems of a novel configuration in accordance with section 6.4.16.

1.2 Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 6.4.1.6. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.

1.3 The limit states are divided into the three following categories:

.1 Ultimate Limit States (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse; under intact (undamaged) conditions;

.2 Fatigue Limit States (FLS), which correspond to degradation due to the effect of cyclic loading; and

.3 Accident Limit States (ALS), which concern the ability of the structure to resist accident situations.

1.4 Section 6.4.1 through to section 6.4.14 shall be complied with as applicable depending on the fuel containment system concept.

2 DESIGN FORMAT

2.1 The design format in this standard is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, L_d, do not exceed design resistances, R_d, for any of the considered failure modes in any scenario:

$$L_d < R_d$$

A design load F_{dk} is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where:

γ_f is load factor; and

F_k is the characteristic load as specified in section 6.4.9 through to section 6.4.12.

A design load effect L_d (e.g. stresses, strains, displacements and vibrations) is the most unfavourable combined load effect derived from the design loads, and may be expressed by:

$$L_d = q(F_{d1}, F_{d2,\ldots,}F_{dN})$$

where q denotes the functional relationship between load and load effect determined by structural analyses.

The design resistance R_d is determined as follows:

$$R_d = \frac{R_k}{\gamma_R \cdot \gamma_C}$$

where:

R_k is the characteristic resistance. In case of materials covered by Chapter 7, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;

γ_R is the resistance factor, defined as $\gamma_R = \gamma_m \cdot \gamma_s$;

γ_m is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);

γ_s is the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis; and

γ_C is the consequence class factor, which accounts for the potential results of failure with regard to release of fuel and possible human injury.

2.2 Fuel containment design shall take into account potential failure consequences. Consequence classes are defined in table 1, to specify the consequences of failure when the mode of failure is related to the Ultimate Limit State, the Fatigue Limit State, or the Accident Limit State.

Table 1: Consequence classes

Consequence class	Definition
Low	Failure implies minor release of the fuel.
Medium	Failure implies release of the fuel and potential for human injury.
High	Failure implies significant release of the fuel and high potential for human injury/fatality.

3 REQUIRED ANALYSES

3.1 Three-dimensional finite element analyses shall be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes shall be identified to avoid unexpected failures. Hydrodynamic analyses shall be carried out to determine the particular ship accelerations and motions in irregular waves, and the response of the ship and its fuel containment systems to these forces and motions.

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

3.3 Fatigue and crack propagation analysis shall be carried out in accordance with paragraph 5.1 of this standard.

4 ULTIMATE LIMIT STATES

4.1 Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength shall be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance (dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities).

4.2 Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in table 2 shall be used for the assessment of the ultimate limit states.

Table 2: Partial load factors

Load combination	Permanent loads	Functional loads	Environmental loads
'*a*'	1.1	1.1	0.7
'*b*'	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination 'a' are relevant for the normally well-controlled and/or specified loads applicable to fuel containment systems such as vapour pressure, fuel weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.

4.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Administration.

4.4 In cases where structural failure of the fuel containment system are considered to imply high potential for human injury and significant release of fuel, the consequence class factor shall be taken as γ_c = 1.2. This value may be reduced if it is justified through risk analysis and subject to the approval by the Administration. The risk analysis shall take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended fuel. Conversely, higher values may be fixed by the Administration, for example, for ships carrying more hazardous or higher pressure fuel. The consequence class factor shall in any case not be less than 1.0.

4.5 The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the fuel containment systems as described in sections 6.4.2.1 to 6.4.2.5. This may be carried out by calibrating the factors against known successful designs.

4.6 The material factor γ_m shall in general reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in Chapter 6, the material factor γ_m may be taken as:

.1 when the characteristic mechanical properties specified by the Administration typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or

.2 when the characteristic mechanical properties specified by the Administration represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.7 The partial resistance factors γ_{si} shall in general be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

4.7.1 For design against excessive plastic deformation using the limit state criteria given in paragraph 4.8 of this standard, the partial resistance factors y_{si} shall be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = Min(\frac{R_m}{R_e} \cdot \frac{B}{A}; 1.0)$$

$$\kappa_2 = Min(\frac{R_m}{R_e} \cdot \frac{D}{C}; 1.0)$$

Factors A, B, C and D are defined in 6.4.15.2.3.1. R_m and R_e are defined in 6.4.12.1.1.3.

The partial resistance factors given above are the results of calibration to conventional I type B independent tanks.

4.8 Design against excessive plastic deformation

4.8.1 Stress acceptance criteria given below refer to elastic stress analyses.

4.8.2 Parts of fuel containment systems where loads are primarily carried by membrane response in the structure shall satisfy the following limit state criteria:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

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

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

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

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

where:

σ_m = equivalent primary general membrane stress
σ_L = equivalent primary local membrane stress
σ_b = equivalent primary bending stress
σ_g = equivalent secondary stress

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

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

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component (σ_x, σ_y, τ_{xy}), and subsequently the equivalent stress shall be calculated based on the resulting stress components as shown in the example below.

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}$$

4.8.3 Parts of fuel containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

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

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

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_{g} \leq 3.0F$$

Note 1: The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

Note 2: The coefficient, 1.25, may be modified by the Administration considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

where:

σ_{ms} = equivalent section membrane stress in primary structure
σ_{bp} = equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure
σ_{bs} = section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure
σ_{bt} = section bending stress in tertiary structure
σ_{g} = equivalent secondary stress

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

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

The stresses σ_{ms}, σ_{bp}, σ_{bs}, and σ_{bt} are defined in 4.8.4.

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component (σ_x, σ_y, τ_{xy}), and subsequently the equivalent stress shall be calculated based on the resulting stress components.

Skin plates shall be designed in accordance with the requirements of the Administration. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.

4.8.4 Section stress categories

Normal stress is the component of stress normal to the plane of reference.

Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in paragraph 4.8.2 of this standard.

Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action, as illustrated in figure 1.

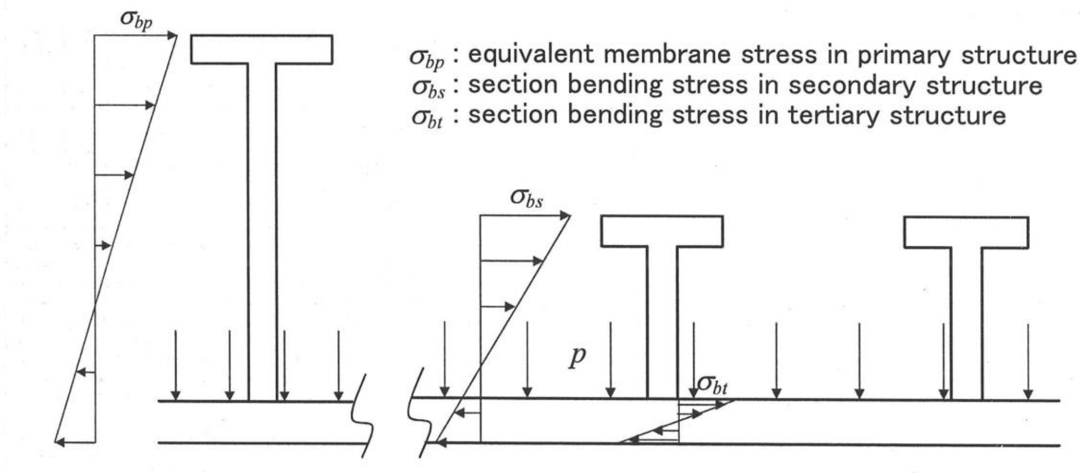

Figure 1: Definition of the three categories of section stress
(Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.9 The same factors y_c, y_m, y_{si} shall be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case the overall level of safety shall not be less than given by these factors.

5 FATIGUE LIMIT STATES

5.1 Fatigue design condition as described in 6.4.12.2 shall be complied with as applicable depending on the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under 6.4.16 and this standard.

5.2 The load factors for FLS shall be taken as 1.0 for all load categories.

5.3 Consequence class factor y_c and resistance factor y_R shall be taken as 1.0.

5.4 Fatigue damage shall be calculated as described in 6.4.12.2.2 to 6.4.12.2.2.5. The calculated cumulative fatigue damage ratio for the fuel containment systems shall be less than or equal to the values given in table 3.

Table 3: Maximum allowable cumulative fatigue damage ratio

	Consequence class		
c_w	Low	Medium	High
	1.0	0.5	0.5*

Note*: Lower value shall be used in accordance with 6.4.12.2.7 to 6.4.12.2.9, depending on the detectability of defect or crack, etc.

5.5 Lower values may be fixed by the Administration.

5.6 Crack propagation analyses are required in accordance with 6.4.12.2.6 to 6.4.12.2.9. The analysis shall be carried out in accordance with methods laid down in a standard recognized by he Administration.

6 ACCIDENT LIMIT STATES

6.1 Accident design condition as described in 6.4.12.3 shall be complied with as applicable, depending on the fuel containment system concept.

6.2 Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario.

6.3 The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.4 Loads mentioned in 6.4.9.3.3.8 and 6.4.9.5 need not be combined with each other or with environmental loads, as defined in 6.4.9.4.

6.5 Resistance factor YR shall in general be taken as 1.0.

6.6 Consequence class factors Yc shall in general be taken as defined in paragraph 4.4 of this standard, but may be relaxed considering the nature of the accident scenario.

6.7 The characteristic resistance Rk shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.8 Additional relevant accident scenarios shall be determined based on a risk analysis.

7 TESTING

7.1 Fuel containment systems designed according to this standard shall be tested to the same extent as described in 16.2, as applicable depending on the fuel containment system concept.

ANNEX 2
RISK ASSESSMENT AS REQUIRED BY THE IGF CODE (IACS REC.146))

1.1 General

To help eliminate or mitigate risks a risk assessment is required by the IGF Code[1]. In this regard it requires that the risk assessment is undertaken using acceptable and recognised techniques, and the risks and their mitigation are documented to the satisfaction of the Administration.

[1] International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) - as adopted at MSC 95 (June 2015)

It is recognised that there are many acceptable and recognised techniques and means to document a risk assessment. As such, it is not the intent of this document to limit a risk assessment to a particular technique or means of documentation. This document does, however, describe recommended practice and examples to help satisfy the IGF Code.

1.2 Risk assessment – Objective

The objective or goal of the risk assessment, as noted in the IGF Code, is to help "eliminate or mitigate any adverse effect to the persons on board, the environment or the ship"[2]. That is, to eliminate or mitigate unwanted events related to the use of low-flashpoint fuels that could harm individuals, the environment or the ship.

[2] IGF Code (ref 1 of this document), Part A, Chapter 4.1.

1.3 Risk assessment – Scope

The IGF Code requires the risk assessment to cover the use of low-flashpoint fuel[3]. This is taken to mean assessment of the supply of such fuel to consumers and covers:

[3] IGF Code (ref 1 of this document), Part A, Chapter 4.2, Paragraph 4.2.1.

- equipment installed on board to receive, store, condition as necessary and transfer fuel to one or more engines, boilers or other fuel consumers;

  Such equipment includes manifolds, valves, pipes/lines, tanks, pumps/compressors, heat exchangers and process instrumentation from the bunker manifold(s) to delivery of fuel to the consumers.

- equipment to control the operation;

  For example, pressure and temperature regulators and monitors, flow controllers, signal processors and control panels.

- equipment to detect, alarm and initiate safety actions;

  For example, detectors to identify fuel releases and subsequent fires, and to initiate shutdown of the fuel supply to consumers.

- equipment to vent, contain or handle operations outside of that intended (i.e. outside of process norms);

  For example, vent lines, masts and valves, overflow tanks, secondary containment, and ventilation arrangements.

- fire-fighting appliances and arrangements to protect surfaces from fire, fuel contact and escalation of fire;

  For example, water sprays, water curtains and fire dampers.

- equipment to purge and inert fuel lines;

For example, equipment to store and supply nitrogen for the purposes of purging/inerting bunker lines, and equipment used for the safe transfer/disposal of fuel.

- structures and constructions to house equipment;

For example, fuel storage hold spaces, tank connection spaces and fuel preparation rooms.

In agreement with stakeholders (e.g. the Administration) the scope can exclude items that have been previously subjected to a risk assessment, provided there are no changes to 'context of use' and mitigation measures taken as a result of previous risk assessment are to be included. This can help reduce assessment time and effort.

The term 'context of use' (used above) refers to differences, such as differences in design or arrangement, installed location, mode of operation, use of surrounding spaces, and the number and type of persons exposed. For example, if an item is located on a cargo ship on-deck, it is a change to the 'context of use' if the same item is then installed below deck on a passenger ship. In addressing 'context of use' it is important to recognise that these 'differences' can significantly decrease or increase risk resulting in the need for fewer, more, changed or alternative means to eliminate or mitigate the risks.

With regards to liquefied natural gas (LNG), the IGF Code states that risk assessment "need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex"[4]. Hence, the IGF Code allows the scope of the risk assessment to be limited to these paragraphs. It is important to note that there are differences of opinion on the scope of risk assessment required by these paragraphs. Therefore, the views of stakeholders and approval by the Administration should be sought when finalising the scope of the risk assessment.

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[4] IGF Code (ref 1 of this document), Part A-1, Chapter 4.2, Paragraph 4.2.2.

The risk assessment includes consideration of bunkering equipment installed on board but does not cover the bunkering operation of: ship arrival, approach and mooring, preparation, testing and connection, fuel transfer, and completion and disconnection. Bunkering of fuel is the subject of separate assessment as per ISO/TC18683 and reference should be made to appropriate and specific guidance.

The IGF Code requires that consideration is given to physical layout, operation and maintenance. Typically, the risks associated with maintenance are controlled by job specific risk assessments before the activity is undertaken. Therefore, consideration of maintenance is taken to mean high-level consideration of design and arrangements to facilitate a safe and appropriate working environment. This requires consideration of, for example, equipment isolation, ventilation of spaces, emergency evacuation, heating and lighting, and access to equipment. The purpose of this is to minimise the likelihood of unwanted events resulting in harm during maintenance. In addition, the purpose is to minimise the likelihood of unwanted events after maintenance, as a result of deficient work where a contributory cause was 'a poor working environment'.

The assessment should also appreciate potential systems integration issues such as equipment control and connection compatibility. This is particularly important where a number of stakeholders are involved in separate elements of design, supply, construction and installation.

Occupational risks can be excluded from the risk assessment. They are an important safety consideration and are expected to be covered by the safety management system of the ship.

The scope should obviously cover the design and arrangement as installed on board. Therefore, where the risk assessment is undertaken prior to finalising the design, it may require revision to ensure that the risks remain 'mitigated as necessary'.

The IGF Code makes no reference to periodic update of the risk assessment. This should be undertaken where changes to the design/arrangement and/or its operation have been made, and in response to changes in performance of equipment and controls. This helps ensure the risks are 'mitigated as necessary' through-out the life of the fuel system.

The final scope of the risk assessment should be agreed with appropriate stakeholders (e.g. the Administration) and guided by applicable classification rules and the IGF Code.

1.4 Risk assessment – Approach

IMO has published guidance on formal safety assessment (FSA) and this provides useful information on risk assessment approaches and criteria[5)]. The purpose of the guidance is to help evaluate new regulations on maritime safety and protection of the environment. In this regard, assessment is focused on risk quantification and cost benefit analysis to inform decision-making. As such, it is a useful reference to IMO's views on risk assessment and criteria. However, the IGF Code does not require a quantitative measure of risk to people, the environment or assets from the use of fuel. The risk assessment is simply required to provide information to help determine if further measures are needed to 'eliminate' risks or to ensure they are 'mitigated as necessary'. Therefore, a qualitative or semi-quantitative approach to the risk assessment is appropriate (i.e. Qualitative Risk Assessment, QualRA[6)]). That is not to say that a fully quantitative approach is inappropriate or that circumstances might not favour its use (i.e. Quantitative Risk Assessment, QRA). What is important is that the risk assessment is of sufficient depth to help demonstrate that risks have been 'eliminated' or 'mitigated as necessary'.

5) Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.

6) Where some form of quantification occurs, then the approach is semi-quantitative. However, such approaches are often referred to as qualitative and this term is used throughout this document.

As a minimum, the risk assessment should detail:

A. how the low-flashpoint fuel could potentially cause harm – Hazard identification;

   That is, systematic identification of unwanted events that could result in, for example, major injuries or fatality, damage to the environment, and/or loss of structural strength or integrity of the ship.

B. the potential severity of harm – Consequence analysis;

   That is, the potential severity of harm (i.e. consequences) expressed in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact, and structural/ship damage sufficient to compromise safe operations.

C. the likelihood of harm – Likelihood analysis;

   That is, the probability or frequency with which harm might occur.

D. a measure of risk – Risk analysis;

   That is, a combination of consequence (B) and likelihood (C).

E. judgements on risk acceptance – Risk assessment.

   The measure of risk (D) should be compared against criteria to judge if the risk has been 'mitigated as necessary'.

Acceptable and recognised techniques to address the requirements noted above (i.e. A-D) are described in, for example, ISO 31010[7)], ISO 17776[8)], ISO 16901[9)], NORSOK Z-013[10)], CPR 12E[11)], and publications by CCPS[12)] and HSE[13)], etc.

7) Risk management: Risk assessment techniques. IEC/ISO 31010:2009.

8) Petroleum and natural gas industries - Offshore production installations - Guidelines on tools and techniques for hazard identification and risk assessment. EN ISO 17776:2002.

9) Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface. ISO/TS 16901:2015.

10) Risk and emergency preparedness assessment. NORSOK Standard Z-013, Edition 3, October 2010.

11) Methods for determining and processing probabilities. CPR 12E, 1997/2005.

12) e.g. Guidelines for chemical process quantitative risk analysis. Centre for Chemical Process Safety, American Institute of Chemical Engineers, Second Edition, 2000.

13) e.g. Marine risk assessment. Health & Safety Executive, 2001.

The following sub-section, A1.4.1, outlines an approach to meeting the above requirements.

1.4.1 An approach to satisfying the IGF Code requirements - Qualitative Risk Assessment (QualRA)

A. Hazard identification

1. Divide the fuel system into discrete parts with respects to equipment function and location.

   This promotes systematic consideration of each part of the system and helps identify specific causes of unwanted events related to a particular item, activity or section. A typical division of the system might be, for example: (a) the bunker station and fuel lines to the storage tank; (b) the fuel storage hold space; (c) the tank connection space; (d) the fuel preparation room; and (e) the fuel lines and valves 'regulating' fuel delivery to the engine.

2. Develop a set of guidewords/phrases and example causes that could result in unwanted events (e.g. a release of fuel or fuel system failure resulting in loss of power).

   The guidewords/phrases and example causes are used as prompts. A typical, but not exhaustive list of prompts is given in Appendix 1.

3. By reference to design and arrangement information, location plans, process flow diagrams, mitigation measures and planned emergency actions use the prompts to identify potential causes of unwanted events (e.g. fuel releases and loss of power).

   The prompts are used to stimulate discussion and ideas within a workshop led by a facilitator and attended by subject matter experts (SMEs).

4. Record the potential causes of unwanted events and mitigation measures

   An example of a record sheet or worksheet is given in Appendix 2. This worksheet is also used to record steps B to E below, and forms part of the overall documentation of the risk assessment.

B. Consequence analysis

5. For each identified cause, estimate the potential consequences in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact and damage sufficient to compromise safe operations.

   The potential consequences can be estimated by the SMEs using judgement and reference to: (a) the fuel's properties/hazards; (b) the release location; (c) dispersion/leak pathways; (d) location and 'strength' of ignition sources; (e) proximity of vulnerable receptors; (f) generic or (if commissioned) specific fire and explosion modelling; and (g) expected effectiveness of existing/planned mitigation measures. The properties and hazards of liquefied natural gas (LNG) noted in (a) are summarised in Appendix 3.

6. Categorise the consequence estimates.

The consequences can be categorised by the SMEs to provide an indication of severity. For example, categories for harm to persons can distinguish between major injury, single fatality and multiple fatalities. Example consequence categories are given in Appendix 4.

C. Likelihood analysis

7. Estimate the annual likelihood of occurrence of 'cause and consequence'.

Likelihood can be estimated by the SMEs (or a suitably qualified individual) for each 'cause-consequence' pair or a grouping of causes with the same consequence. The estimation can be informed by reference to accident and near-miss reports, accident and equipment release data, analogy to accidents in similar or other industries and consideration of the reliability and effectiveness of mitigation measures. It is not always apparent if the likelihood of a 'cause-consequence' combination is credible (i.e. reasonably foreseeable). As a guide, an unwanted event may be considered credible if:

(a) it has happened before and it could happen again;

(b) it has not happened but is considered possible with an annual likelihood of 1 in a million or more; and

(c) it is planned for, that is, emergency actions cover such a situation or maintenance is undertaken to prevent it. A guide to the likelihood of releases relevant to LNG equipment and operations is given in Appendix 5.

8. Categorise the likelihood estimates.

Likelihood can be categorised by the SMEs (or a suitably qualified individual) to provide an indication of accident/incident occurrence or other unwanted event occurrence. Example likelihood categories are given in Appendix 4.

D. Risk analysis

9. Estimate the risk.

Risk can be estimated by the SMEs (or a suitably qualified individual) by combining the consequence and likelihood categories to provide a risk rating. For example, if a 'cause-consequence' pair is categorised as, say 'A', and associated 'likelihood' as, say '1', then the risk rating is 'A1'. An example of a risk rating scheme is given in Appendix 4.

E. Risk assessment

10. Judge if the risk has been 'mitigated as necessary'.

The estimated risk can be compared against risk criteria embedded within a risk matrix. The matrix shows the risk rating (with respects to consequence and likelihood) and the criteria illustrate whether the risk has been 'mitigated as necessary'. An example of a risk rating scheme and its associated risk criteria are given in Appendix 4.

With respects to D and E above, it is important to note that there are no universally agreed risk rating schemes or risk criteria: there are differences between governments, regulators and organisations. Therefore, prior to the commencement of the risk assessment, risk rating/criteria should be agreed with appropriate stakeholders (e.g. the Administration).

It should also be recognised that the risk rating of individual or grouped 'cause-consequence' pairs does not provide an indication of the collective (overall) risk from all potential 'cause-consequence' pairs. If the overall risk level is required then this can be determined using QRA.

Practically, the risk rating is an indication that additional or alternative mitigation measures:

- must be provided; or
- must be considered and implemented if practical and cost effective; or
- need not be considered further, beyond accepted good practice of reducing risk where practicable.

In each of the steps above many assumptions are made and there is uncertainty. Therefore, it is good practice for SMEs to list assumptions and 'test' the sensitivity of results to changes in any of these steps. For example, a change to an assigned consequence or likelihood category could alter the risk rating and the judgement on whether a risk is 'mitigated as necessary'.

1.4.1.1 Mitigated as necessary

The phrase 'mitigated as necessary' is used in the IGF Code and is akin to the phrase 'As Low As Reasonably Practicable', commonly referred to as ALARP. Essentially, a risk is considered ALARP if all reasonably practicable mitigation measures have been implemented. This means that additional or alternative measures have been identified and implemented unless they are demonstrated as impractical or the cost of implementation is disproportionate to the reduction in risk. This concept of ALARP is established practice in many industries and recognised as best practice by IMO[14)].

[14)] Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.

Where 'mitigated as necessary' is not proven then the SMEs should consider additional and/or alternative mitigation measures[15)] and re-evaluate the risk. The risk cannot be 'accepted' until 'mitigated as necessary' is achieved. In this regard, additional study can be undertaken to help the SMEs decide if existing, additional or alternative measures can provide 'mitigated as necessary'.

[15)] Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms 'prevention measures' and 'mitigation measures', where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as 'safeguards' or 'barriers'.

When considering mitigation measures the following hierarchy of mitigation is considered best practice:

- firstly, measures to prevent an unwanted event;

  That is, to ensure the unwanted event cannot occur or its likelihood of occurrence is greatly reduced;

- secondly, measures to protect against harm given an unwanted event.

  That is, to reduce the consequences after the unwanted event has occurred.

In addition, when considering mitigation measures it is good practice to consider **engineering solutions in preference to procedural controls**. This helps promote an inherently safer design. Furthermore, it is good practice to consider **passive measures in preference to active measures**. For example, a passive measure is one where no manual or automated action is required for it to function on demand and as intended. Whereas, an active measure requires some means of activation for it to operate. Both passive and active measures may be required to demonstrate that the risk has been mitigated as necessary. Examples of mitigation measures are listed in Appendix 6.

To help judge if mitigation measures are effective it can be useful to illustrate or map the pathway from 'cause' to 'consequence' and review the effectiveness of the mitigation measures. An example of such mapping and review is given in Appendix 7.

Whether a single mitigation measure or a collection of mitigation measures is practical and cost-effective is in some respects relative to the resources and skills available. If the SMEs cannot decide then the use of cost benefit analysis can be helpful. In any case, a documented justification for not implementing a mitigation measure should be made where SMEs judge the measure to be practical and cost-effective.

1.5 Risk assessment – Team

The team conducting the risk assessment should comprise of subject matter experts (SMEs) who are, collectively, suitably qualified and experienced. For the QualRA noted above, this means the workshop team includes individuals who are degree qualified and/or chartered/professional engineers, have operational ship experience and are experienced in risk assessment. Such qualifications and experience should be in relevant disciplines to cover engineering design and safe use of the fuel.

It is unlikely that one SME can satisfy the above team requirements. In any case, to ensure investigative discussion, generation of ideas, challenge and coverage of, for example, mechanical, process, electrical and operational aspects, a typical number of SMEs might be four to eight.

In addition to the SMEs, the team should be led by a facilitator (also referred to as the chair or chairman). The facilitator should be impartial with no vested interests in the fuel system, and experienced in leading such risk assessments. The facilitator may be supported by a scribe (also referred to as a secretary) to aid reporting.

The time expended by the team depends upon the agreed scope and the designs' 'complexity'. For example, a QualRA workshop for a new design might require two or three working days, whereas, a minor variation to a previously assessed and approved design might require only half a day.

1.6 Risk assessment – Reporting

1.6.1 Main report

A written report documenting the risk assessment should be produced. This needs to be sufficiently detailed to support results, conclusions, recommendations and any actions taken. This is because the assessment will inform important design and operational decisions. Furthermore, the report is a record in helping to demonstrate 'mitigated as necessary'. A report only consisting of a completed worksheet is insufficient.

The specific contents of the report and its structure are dependent upon design and assessment specifics, and reporting preferences. However, for a QualRA, the report should provide:

- an overview of the design and arrangement;

  This is a simple explanation of the design and arrangement with respects to its intended operation and process conditions. Technical appendices should include process flow diagrams, general arrangement plans and all information used during the assessment. Where this is too cumbersome to include in the report in full, reference to this material is sufficient provided it remains accessible.

- an explanation of the risk assessment process;

  This is a description of the risk assessment method and includes how the design was divided into parts for assessment, how hazard identification was undertaken, and the selection of consequence and likelihood categories and risk criteria.

- information on the relevant qualifications and expertise of the team;

  This can be a table listing the names, job titles, relevant qualifications, expertise and experience of all team members (including the facilitator and scribe). It is not sufficient to simply list names and job titles.

- the time taken to complete the assessment and whether SMEs were present to provide their expert input;

  For a workshop, this can be a table listing the schedule/duration and attendance of each SME (i.e. full-time or part-time, and if part-time the 'parts' for which the person was absent). The purpose of this is to indicate if sufficient time was taken to assess the design/arrangement, and to highlight any SME absences that could be detrimental to results, conclusions and actions. For any SME absences, a note should be made by the facilitator as to whether this impacted adversely upon the assumptions and judgements made.

- risk results and conclusions;

  This is a listing or discussion of the results and a judgement on whether or not the risk has been 'mitigated as necessary'.

- recommendations and actions.

  This can include requests for modelling and analysis (e.g. gas dispersion or thermal radiation extent, etc.) and will most likely include additional and alternative mitigation measures to be investigated and/or implemented, who is responsible for these and, if known, an expected completion date. It is important that these recommendations and actions are suitably documented because they are likely to be used to plan a response and monitor progress until the recommendations/actions have been addressed.

An example report contents is given in Appendix 8.

1.6.2 Terms of reference (ToR)

Prior to the workshop it is good practice for the facilitator to issue relevant information to the team. This is sometimes referred to as a terms of reference (ToR). This helps the team familiarise with the design and intended approach before the workshop. It also provides time for clarifications and agreement with the proposed consequence and likelihood categories and risk criteria. Importantly, it provides time to confirm the suitability of the proposed schedule and team. The ToR can form an appendix to the main report.

Typically, a ToR includes:

- objectives and scope of the assessment;

  This is to ensure all team members understand the objective and what equipment and operations are to be covered in the assessment.

- technical description of the proposed design and arrangements;

  This can include copies of process flow diagrams (PFDs) or schematics detailing process conditions of equipment and pipework, and a scaled layout drawing illustrating equipment and pipework arrangements, size and location.

- overview of the potential consequences of a fuel release;

  For LNG, this could refer to Appendix 3 of this document.

- technique to be used;

  This includes proposed consequence and likelihood categories and risk criteria.

- intended workshop schedule;

  This highlights the time to be given to the workshop and when SME input is required.

- team details.

This includes the name and job title, relevant qualifications, expertise and experience of each SME and team member/workshop attendee.

Appendix 1
Prompts - guidewords and phrases

Example prompts for use in QualRA

Failure of fuel containing equipment* – a hole/crack leading to release of fuel	
Wear and tear	vibration, loading, cycling, prolonged use
Erosion	fuel contaminants, high stream velocity, prolonged use
Stress and strain	vibration, loading, cycling, ship movement, prolonged use
Fatigue	vibration, loading, cycling, ship movement, prolonged use
Corrosion	exposure to weather, exposure to sea water, humidity, loss of dry air supply, contact with corrosive materials
Collision	ship collides with another vessel, ship hits rocks, ship strikes the harbour wall or jetty
Grounding	ship runs aground
Impact	dropped object (e.g. during maintenance or cargo loading), collapse of supporting structure, maloperation during loading/maintenance
Fire	ignition of flammable materials, fire in adjacent spaces/areas
* plus equipment containing gases or other substances that could release into spaces resulting in harm (e.g. asphyxiation, burns)	
Failure of process control – operation outside of design conditions leading to subsequent release of fuel	
Temperature high	loss of insulation, instrument failure, software failure, actuator failure, maloperation by operator, external fire, exposure to extreme weather, decomposition
Temperature low	loss of heating medium circulation, heating medium contamination, instrument failure, software failure, actuator failure, maloperation by operator, exposure to extreme weather
Pressure high	maloperation by operator (e.g. closed valve), loss of utilities (e.g. instrument air), external fire, loss of power supply, rollover, excess generation of boil-off gas, actuator failure
Pressure low (vacuum)	maloperation by operator, loss of utilities (e.g. instrument air), loss of power supply (electricity), actuator failure
Flow high	instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Flow low	instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Flow reversed	instrument failure, software failure, maloperation by operator (e.g. closed valve), exposure to extreme sea conditions
No Flow	instrument failure, software failure, maloperation by operator (e.g. closed valve), actuator failure
Level high	instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Level low	instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions
Fuel left in pipe/line	maloperation by operator, closed valves, no inert/purge supply, limited inert/purge supply
No fuel in pipe/line	instrument failure, software failure, maloperation by operator, closed valves
Loss of power	loss of electrical signals, blackout, loss of instrument air, loss of hydraulic fluid

Note: Poor manufacturing, installation and commissioning of equipment can increase the likelihood and/or consequences of fuel releases. If these aspects are not covered and controlled by, for example, class rules, then they should be included in the risk assessment. The assessment should cover intended operation, shutdown and start-up.

Appendix 2
Record sheet / Worksheet

Worksheet Example

Worksheet for [project title]											
Part or Section [title]											
						Category & Rating					
Item/ Activity	Guideword/ Phrase	Causes (accident/incident)	Consequences	Mitigation (existing safeguards)	Additional/Alternative Mitigation safeguards)	Consequence	Likelihood	Risk	Mitigated as necessary	Recommendations Comments/Actions	Action by/date

Note: The worksheet can be used to record risk ratings before and after consideration of additional/alternative safeguards by using one row for 'existing safeguards' and one row for 'additional/alternative safeguards'. If preferred, the 'Additional/Alternative Mitigation (safeguards)' column can be moved after the 'Category & Rating' columns followed by additional 'Category & Rating' columns.

Appendix 3
Properties & hazards of liquefied natural gas

3.1 LNG Properties

Liquefied natural gas (LNG) is a cryogenic liquid. It consists of methane with small amounts of ethane, propane and inert nitrogen. When used as a fuel, typically 94% or more is methane. Stored at ambient or near ambient pressure, its temperature approximates minus 162 °C and its specific gravity is about 0.42. Hence, if released onto the sea LNG floats (and can rapidly 'boil' – refer to 3.2.7). When stored at pressures of up to 10 bar the temperature typically remains below minus 130 °C with a specific gravity of approximately 0.4.

Released into atmospheric conditions, LNG rapidly boils forming a colourless, odourless and non-toxic gas. Although colourless, due to its very low temperature, water vapour in the air condenses forming a visible mist or cloud. The cold gas is initially heavier than air and it remains negatively buoyant until its temperature rises to about minus 100 °C. At this stage the gas becomes lighter than air, and in an open environment it is thought that this coincides with a gas concentration of less than 5%. At this temperature and concentration the gas is still within the visible cloud. As the gas continues to warm to ambient conditions its volume is approximately 600 times that of the liquid with a relative vapour density of about 0.55, and so the gas is much lighter than air (air = 1).

As the gas disperses, its concentration reduces. At a concentration in air of between 5% and 15% the mix is flammable and can ignite in the presence of ignition sources or in contact with hot sources at or above a temperature of approximately 595 °C (referred to as the auto-ignition temperature). Once below a concentration of 5% the mix is no longer flammable and cannot be ignited (and this is the case if the concentration remains above 15%). The 15% and 5% concentrations of LNG in air are commonly known as the upper and lower flammability limits, respectively. More recently, the limits are referred to as the upper and lower explosion limits, although ignition may not necessarily result in explosion.

3.2 LNG Hazards

3.2.1 Cryogenic burns

Owing to its very low liquid temperature, in contact with the skin LNG causes burns. In addition, breathing the cold gas as it 'boils' can damage the lungs. The severity of burns and lung damage is directly related to the surface area contacted by the liquid/gas and duration of exposure.

3.2.2 Low temperature embrittlement

In contact with low temperature LNG, many materials lose ductility and become brittle. This includes carbon and low alloy steels typically used in ship structures and decking. Such low temperature embrittlement can result in material fracture, such that existing stresses in the contacted material cause cracking and failure even without additional impact, pressure or use. For LNG duty, materials resistant to low temperature embrittlement are used. These materials include stainless steel, aluminium, and alloy steels with a high-nickel content.

3.2.3 Asphyxiation

LNG is non-toxic and is not a known carcinogen. However, as it boils to gas it can cause asphyxiation as it displaces and then mixes with the surrounding air. The likelihood of asphyxiation is related to the concentration of gas in air and duration of exposure.

3.2.4 Expansion and pressure

Released into the atmosphere LNG will rapidly boil with the volume of gas produced being hundreds of times that of the liquid (approximately 600 times at ambient conditions). Hence, if confined and unrelieved, the pressure will increase and this can damage surrounding structures and equipment.

3.2.5 Fire

3.2.5.1 Pool fire

A 'small' release of LNG will rapidly boil and 'flash' to gas (i.e. evaporate). However, given a 'large' and sudden release, a cold pool of LNG will form with gas boiling from the pool and mixing and dispersing with the surrounding air. If this mix is within the flammable range (i.e. 5% to 15% with air) and contacts an ignition source or a heated surface above the auto-ignition temperature (595 °C) it will ignite and the resultant flame will 'travel back' to the pool resulting in a pool fire.

3.2.5.2 Jet fire

If stored under pressure then a release of LNG may discharge as a jet of liquid, entraining, vapourising and mixing with air. If the mix disperses and reaches an ignition source or a heated surface (above the auto-ignition temperature) whilst in the flammable range it will ignite. The resultant flame will 'travel back' and may result in a pressurised jet fire from the release source. Similarly, where contained LNG has been heated to form gas, a pressurised release of this gas could ignite and result in a jet fire.

3.2.5.3 Flash fire

Release of LNG to atmosphere and ignition within a few tens of seconds is likely to result in a pool fire or jet fire (as noted above) with no damaging overpressure. This is because the flammable part of the cloud is likely to be relatively small and close to the release point upon ignition. However, if ignition is delayed, the gas cloud will be larger and may have travelled further from the release point. Ignition will then result in a flash fire as the flammable part of the cloud is rapidly consumed within a few seconds. This ignition is likely to be violent and audible, and is often mistaken for an explosion, although there is little appreciable overpressure.

3.2.5.4 Thermal radiation from a pool fire, jet fire and flash fire

Harm to people and damage to structures and equipment from fire is dependent upon the size of the fire, distance from the fire, and exposure duration. Within a metre of the fire, thermal radiation may approximate 170 kW/m2 but this rapidly falls with distance from the fire.

As a rough guide:

- 6 kW/m^2 or more and escape routes are impaired and persons only have a few minutes or less to avoid injury or fatality[16)];
- 35 kW/m^2 results in immediate fatality[16)];
- 37.5 kW/m^2 has long been considered as the onset of damage to industrial equipment and structures exposed to a steady state fire[17)];
- industrial equipment and structures within a flash fire are unlikely to be significantly damaged; and
- persons within a pool, jet or flash fire are likely to be fatally injured.

An LNG fire on a ship could result in fatalities and damage to equipment and structures (including the hull).

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16) There are many quoted values from many sources and with inconsistencies. Thermal dose might be alternatively used. The values quoted here are based on: Health & Safety Executive, Indicative human vulnerability to the

hazardous agents present offshore for application in risk assessment of major accidents, SPC/Tech/OSD/30, 2011, and supporting document: Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment, http://www.hse.gov.uk/foi/internalops/hid_circs/technical_osd/spc_tech_osd_30/spctecosd30.pdf

17) Risk Analysis of Six Potentially Hazardous Industrial Objects in the Rijnmond Area, A Pilot Study. (1982). D. Reidel Publishing Company, The Netherlands.

3.2.6 Explosion

Release of LNG to atmosphere and delayed ignition of the resultant flammable cloud beyond a few tens of seconds can result in an explosion. This is because the cloud may have dispersed in and around equipment and structures causing a degree of confinement and increased surface area over which to increase flame speed as it travels (i.e. burns) through the flammable mixture. The resultant overpressure may be sufficient to harm individuals, and damage structures and equipment. Such an explosion is most likely to be a deflagration (rather than a detonation), categorised by high-speed subsonic combustion (i.e. the rate at which the flame travels through the flammable cloud).

3.2.6.1 Overpressure from an explosion

Harm to people and damage to structures and equipment from an explosion is dependent upon the magnitude of overpressure generated and the rate at which the overpressure is delivered (known as impulse). In addition, harm is often a result of falling or being thrown against hard surfaces or being struck by objects and debris as a result of the blast. As a rough guide:

- the probability of fatality from exposure to an explosion of 0.25 bar and 1 bar is about 1% and 50%, respectively[18)];
- less than 0.25 bar could throw an individual against a hard surface resulting in injury or fatality[18)]; and
- 0.3 bar is typically the limit of damage to structures and industrial equipment[18].

18) There are many quoted values from many sources and with inconsistencies. Impulse might be alternatively used. The values quoted here for fatality and damage are based on Ref 16 and Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials, CPR 16E, Labour Inspectorate, The Netherlands.

An explosion of vapourised LNG on a ship could result in fatalities and damage to equipment and structures (including the hull).

3.2.7 Rapid phase transition

Upon release, LNG rapidly boils due to heat from the surrounds, be this from the air, water/sea, steel or ground. However, this rapid and sometimes violent boiling is not rapid phase transition (RPT); RPT is an explosive vaporisation of the liquid, that is, a near instantaneous transition from liquid to gas. This is a more violent event than rapid boiling and it can result in liquid ejection and damaging overpressure[19)]. The phenomenon is well known in the steel industry, where accidental contact between molten metal and water can result in RPT.

19) Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.

3.2.8 Rollover

Slowly, stored refrigerated LNG evaporates (i.e. 'boils-off') as heat from the surrounds gradually 'leaks' into the tank. Essentially, liquid in contact with the wall of the tank warms, becomes less dense and rises to the top. This top-layer then begins to evaporate (i.e. boil-off) increasing the liquid layer's density. Liquid further away from the walls also warms but at a slower rate and because of this a less dense layer below the top layer forms. Owing to the hydrostatic head, the saturation condition of this layer changes and although it heats-up, it does not evaporate but remains in the liquid state and becomes 'superheated'. As the heating continues, the trapped layer's density reduces; this is an unstable state and when the density of this layer is similar to the top layer the two layers rapidly mix and the superheated lower layer vaporises. This rapid mixing and vaporisation is known as rollover and can cause damaging over-pressure and release of gas if not appropriately controlled.

The heating mechanism described above can result in a number of differing layers and is referred to as stratification. It is a phenomenon that is well known and is safely managed through venting, mixing and temperature control.

The above phenomenon is hastened by, or can directly occur when differing densities of LNG are bunkered.

3.3 References

The information and facts given in this appendix are well known and have been recorded in numerous papers and reports on LNG. However, original sources are not always readily available (or known) and so the information given in this section was cross-checked by reference to:

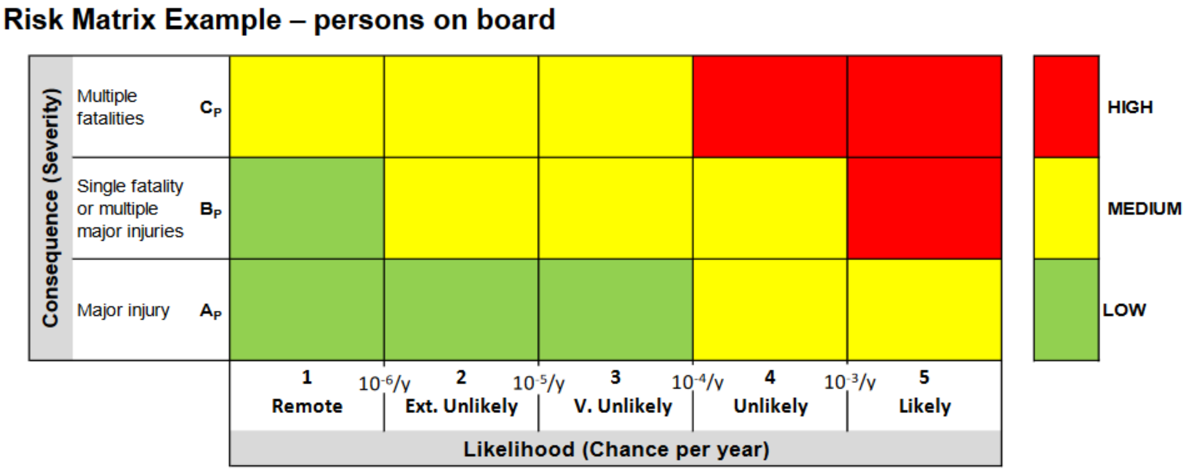
1. Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.
2. International Maritime Organization, Marine Safety Committee. (2007). FSA – Liquefied Natural Gas (LNG) Carriers, Details of the Formal Safety Assessment. MSC 83/INF.3.
3. Bull, D. and Strachan, D. (1992). Liquefied natural gas safety research.
4. Sheats, D. & Capers, M. (1999). Density Stratification in LNG Storage. Cold Facts, 15/2.
5. Bashiri, A. & Fatehnejad, L. (2006). Modelling and Simulation of Rollover in LNG Storage Tanks. 23rd World Gas Conference, Amsterdam.

Reference can also be made to ISGOTT (International Safety Guide for Oil Tankers and Terminals) Publication (2009) – Report on the Effects of Fire on LNG Carrier Containment Systems.

Comparison of the Hazards of LNG and Fuel Oil

Hazards	LNG	Fuel Oil[1]
1. **Cryogenic Burns** Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.	✓	X
2. **Low Temperature Embrittlement** Equipment/structures can fail on contact with liquid.	✓	X
3. **Rapid Phase Transition (RPT)** Released onto the sea a near instantaneous 'explosive' transition from liquid to gas can occur. This can result in structural damage to the hull.	✓	X
4. **Gas Expansion** A liquid pool rapidly boils, and as the gas warms and expands it requires a volume 600 times that of the liquid. This can result in equipment damage.	✓	X
5. **Asphyxiation** In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.	✓	✓
6. **Pool Fire** Gas/vapour above the pool can ignite resulting in a pool fire. The intensity of the radiation can cause fatal injury and fail structure and critical equipment.	✓	✓
7. **Flash Fire** Gas/vapour can disperse away from the pool and ignite resulting in a flash fire. The short-duration and intense radiation can instigate secondary fires, and cause fatal injuries to those within the fire and to critical equipment. Most probably the fire will burn back to the pool and result in a pool fire.	✓	X[2]
8. **Explosion** Gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion. The explosion can cause fatal injuries, instigate secondary fires, and fail structure and critical equipment. Most probably the explosion will burn back to the pool/gas source and result in a pool fire or jet fire.	✓	X[2]
9. **Rollover** Stored liquid can stratify, that is different layers can have different densities and temperatures. This can cause the layers to 'rollover' resulting in significant gas/vapour generation that must be contained. If released, this can result in flash fire or explosion.	✓	X
10. **Boil-off Gas (BoG)** LNG continually boils and must be re-liquefied or burnt-off. A release of BoG can ignite and result in a jet fire (given sufficient release pressure), flash fire or explosion.	✓	X
Note: 1. Fuel oil – heavy fuel oil (HFO) (ISO 8217). 2. If a fuel oil is 'sprayed' as an aerosol resulting in fine air-borne droplets, ignition can result in flash fire or explosion.		

Appendix 4
Risk Matrix



Consequence Category Examples

A_P Major injury – *long-term disability/health effect*

B_P Single fatality or multiple major injuries – *one death or multiple individuals suffering long-term disability/health effects*

C_P Multiple fatalities – *two or more deaths*

Likelihood Category Examples

1. Remote – *1 in a million or less per year*
2. Extremely Unlikely – *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely – *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely – *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely – *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_P1, A_P2, A_P3 & B_P1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

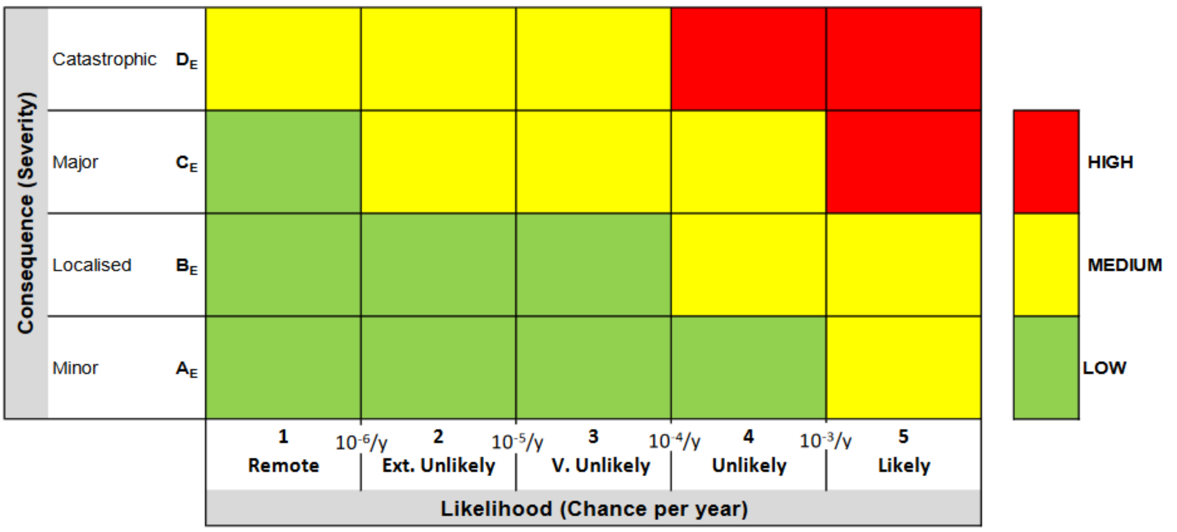
Medium Risk – A_P4, A_P5, B_P2, B_P3, B_P4, C_P1, C_P2 & C_P3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_P5, C_P4 & C_P5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Risk Matrix Example – environment



Consequence Category Examples

A_E Minor – *limited and reversible damage to sensitive areas/species in the immediate vicinity*

B_E Localised – *significant but reversible damage to sensitive areas/species in the immediate vicinity*

C_E Major – *extensive or persistent damage to sensitive areas/species*

D_E Catastrophic – *irreversible or chronic damage to sensitive areas/species*

Likelihood Category Examples

1. Remote – *1 in a million or less per year*
2. Extremely Unlikely – *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely – *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely – *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely – *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_E1, A_E2, A_E3, A_E4, B_E1, B_E2, B_E3 & C_E1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

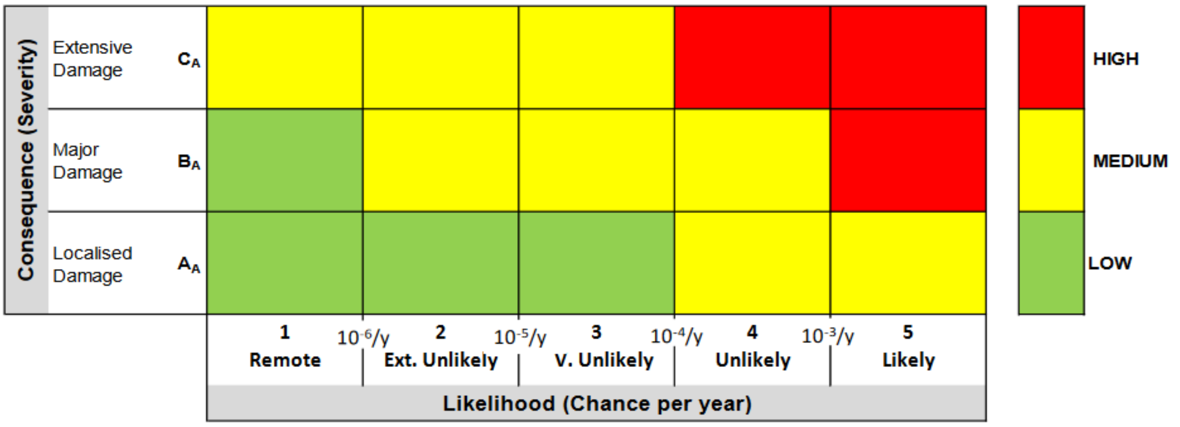
Medium Risk – A_E5, B_E4, B_E5, C_E2, C_E3, C_E4, D_E1, D_E2 & D_E3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative *mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.*

High Risk – C_E5, D_E4 & D_E5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Risk Matrix Example – ship assets (equipment, spaces and structure)



Consequence Category Examples

A_A Localised damage – *an event halting operations for more than x days*

B_A Major damage – *an event halting operations for more than y days*

C_A Extensive damage – *loss of ship, an event halting operations for more than z days*

Likelihood Category Examples

1. Remote – *1 in a million or less per year*
2. Extremely Unlikely – *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely – *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely – *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely – *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_A1, A_A2, A_A3 & B_A1

The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_A4, A_A5, B_A2, B_A3, B_A4, C_A1, C_A2 & C_A3

The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative *mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.*

High Risk – B_A5, C_A4 & C_A5

The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Appendix 5
Likelihood of releases

Indicative likelihood categories

The following table provides indicative likelihood categories as follows: (a) named equipment item fails and releases fuel[20], and (b) collisions and groundings[21].

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[20] Indicative values are based on (a) and (b) and summarised in (c): (a) International Association of Oil & Gas Producers. (1 March 2010). Risk Assessment Data Directory – Process Release Frequencies, Report No. 434 – 1; (b) Health and Safety Executive. (1992-2006). Hydrocarbon Releases (HCR) System. https://www.hse.gov.uk/hcr3/; (c) LNG as a Marine Fuel - Likelihood of LNG Releases. Journal of Marine Engineering & Technology (JMET), Vol. 12, Issue 3, September 2013.

[21] Formal Safety Assessment (FSA): FSA Container Vessels, MSC 83/21/2 (Table 3), 3 July 2007; FSA Cruise Ships, MSC 85/17/1 (Table 1), 21 July 2008; and FSA RoPax Ships, MSC 85/17/2 (Table 1), 21 July 2008.

Likelihood values differ dependent upon source, assumptions made and the inclusion/exclusion of causes, etc. Therefore, it is important to refer to the original data sources to ensure the indicative likelihood category remains valid for specific cases of interest.

Indicative Likelihood Values by Likelihood Category

1. Remote - 1 in a million or less per year (10^{-6}/y or less)			
Type C Fuel Tank	<1 x 10^{-6}		
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year* *(10^{-6}/y to 10^{-5}/y)*			
Leak ≥ 10 mm Ø	**50 mm or less Ø**	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	7 x 10^{-6}	3 x 10^{-6}	3 x 10^{-6}
Flange	4 x 10^{-6}	5 x 10^{-6}	7 x 10^{-6}
Manual Valve	---	7 x 10^{-6}	9 x 10^{-6}
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year* *(10^{-5}/y to 10^{-4}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	8 x 10^{-5}	4 x 10^{-5}	3 x 10^{-5}
Flange	4 x 10^{-5}	5 x 10^{-5}	8 x 10^{-5}
Manual Valve	3 x 10^{-5}	5 x 10^{-5}	7 x 10^{-5}
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year* *(10^{-4}/y to 10^{-3}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Actuated Valve	3 x 10^{-4}	3 x 10^{-4}	3 x 10^{-4}
Instrument Connection	3 x 10^{-4} includes flange		
Process Vessel	7 x 10^{-4} pressurised vessel		
5. Likely - *between 1 in 1,000 and 1 in 100 per year* *(10^{-3}/y to 10^{-2}/y)*			
		50-150 mm Ø	**>151 mm Ø**
Heat Exchanger / Evaporator / Heater		2 x 10^{-3}	2 x 10^{-3}
Pumps (centrifugal or reciprocating)		5 x 10^{-3}	1 x 10^{-3}
Ro-Pax	1 x 10^{-2} collision / 1 x 10^{-2} grounding		
Cruise Ship	5 x 10^{-3} collision / 1 x 10^{-2} grounding		
Container Ship	2 x 10^{-2} collision / 7 x 10^{-3} grounding (data refers to wrecked/stranded)		

The likelihood values include all collisions and groundings. For collisions this means all collisions where the ship is 'struck' and where the ship is the 'striking ship'. The likelihood of interest might be less than the values above when consideration is given to ship, route and incident specifics. For example, assuming a release requires a Ro-Pax ship to be 'struck' and the collision to be 'serious' then the likelihood value approximates 5 x 10^{-4} (i.e. category 4 'Unlikely' where 'struck/striking' is assumed 50/50 and about 10% of collisions are 'serious'[21]).

21) – see previous page

Appendix 6
Mitigation measures

Example mitigation measures

Engineering Mitigation Measures
Protection from mechanical impact damage
Protection from vibration / vibration monitoring
Protection from wind, waves and weather
Pressure relief, venting
Increased separation or increased physical protection from collision / grounding
Secondary containment (e.g. double-walled pipework)
Welded connections in preference to flanged connections
Alarmed and self-closing doors
Bulkhead separation / cofferdam
Drip tray capacity, liquid detection
Spray shield coverage
Protection of structure from cryogenic temperatures and pressure from evolved vapour / gas
Independent bilge
Fire and gas detection, monitoring, audible / visual alarm and shutdown
Pressure and temperature detection, audible / visual monitoring, alarm and shutdown
Level detection
Forced / natural ventilation - airlock
Minimisation of ignition sources - Ex proof electrical equipment
Fire-fighting fire and cooling appliances - foam, water spray
Fire dampers
Separation of spaces
Access arrangements
Physical shielding
Mooring tension monitoring / alarm
Strain monitoring of supports
Buffer / overflow tank - Fuel recycling
Independent safety critical controls to IEC 61508
Radar monitoring
Service fluid - level / gas detection, alarm and shutdown
Flame arrestor
Procedural Mitigation Measures
Increased frequency of inspection (and maintenance)
Reduced parts replacement frequency
Specific training for low-flashpoint fuels
Restricted access
Monitoring
Note: 1. The mitigation measures above are largely generic and in no particular order. They are listed as a simple *aide memoir* when considering mitigation. 2. Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms 'prevention measures' and 'mitigation measures', where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as 'safeguards' or 'barriers'.

Appendix 7
Cause to Consequence Mapping

An established means to illustrate or map the pathway from 'cause' to 'consequence' is known as Bowtie. There are a number of variations on this theme and differing terminologies but essentially the Bowtie helps to visualise: threats or causes of an unwanted event; the barriers or mitigation measures to prevent the unwanted event; and the barriers to mitigate the consequences.

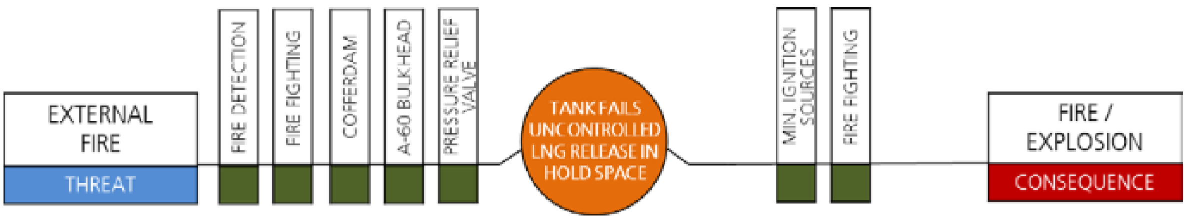
Bowtie examples

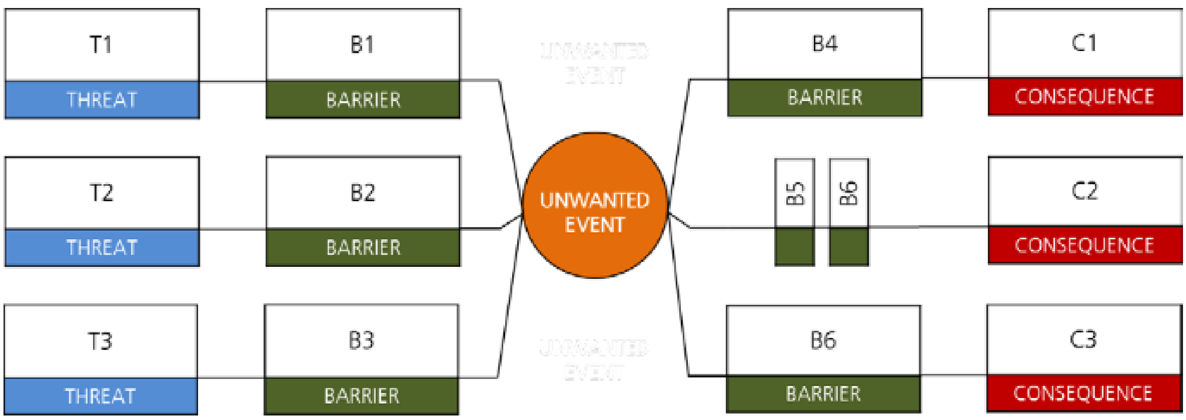
Threat – *A cause that can potentially lead to the unwanted event.*

Barrier – *A mitigation measure that can potentially prevent the unwanted event or its consequences.*

Unwanted Event –*A situation to be avoided e.g. a release of fuel or a loss of ship propulsion.*

Consequence – *An outcome of a threat and an unwanted event not being mitigated by the barriers.*





In respect of 'mitigation measures' (i.e. barriers) those prior to the unwanted event are often referred to as preventative barriers or prevention measures.

Appendix 8
Report Contents

Example report contents

Executive summary	
An overview of the assessment and main results and conclusions.	
1. Introduction	
A brief statement on the purpose of the assessment and the parties involved.	
2. Objective and Scope	
The principal objective is, for example, to demonstrate that the safety-risk is, or can be made acceptable/tolerable for Class approval. The scope is, for example, limited to the design/arrangement, the specific environment/location and the intended modes of operation.	
3. Description	
A simple explanation of the design and arrangement with respects to its intended operation and process conditions.	
4. Approach	
Overview of the risk assessment technique/method. This includes how the design was divided into sections for assessment, how hazard identification was undertaken, the selection of risk criteria, and the mechanism of risk rating and recording. In addition, a note on the actual workshop schedule illustrating the time expended on each section.	
5. Team	
The names, job titles, relevant qualifications, expertise and experience of the facilitator and SMEs. This can be recorded in a table, together with a record of workshop attendance. If this information is particularly large and would detract from the approach and results, the information can be included as an appendix.	
6. Results	
Discussion of the main findings and issues.	
7. Conclusions	
A summary judgement on whether the risks are 'mitigated as necessary'.	
8. Actions	
A listing of additional/alternative safeguards, including who is responsible and expected completion date.	
Appendices	
A.	Worksheets (as recorded in the workshop, including guidewords and phrases i.e. prompts).
B.	Drawings, Process Information and Reference Documents (including the Terms of Reference).

END OF IACS REC.146

LIST OF EXTERNAL REFERENCE DOCUMENTS

IMO documents:

1. MSC.1/Circ.1558 *Unified interpretations of the IGF Code*.
2. MSC.1/Circ.1591 *Unified interpretations of the IGF Code*.
3. MSC.1/Circ.1605 *Unified interpretations of the IGF Code.*
4. MSC.1/Circ.1622 *Guidelines for the acceptance of alternative metallic materials for cryogenic service in ships carrying liquefied gases in bulk and ships using gases or other low-flashpoint fuels.*
5. MSC.1/Circ.1670 *Unified interpretations of the IGF Code.*
6. MSC.458(101) *Amendments to the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code)*
7. MSC.475(102) *Amendments to the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code)*
8. CCC 9/WP.3 *Amendments to the IGF Code and development of Guidelines for Alternative Fuels and Related Technologies*

IACS documents:

1. UI GC9, Rev.1 *Guidance for sizing pressure relief systems for interbarrier spaces*

2. UI GF1 New *Test for gas fuel tank's high level alarm*
3. UI GF2 New *Ship Steel Protection against Liquefied Gas Fuel (Part A-1, paragraph 6.3.10)*
4. UI GF3 New *Tank connection space for tanks on open deck and tank connection space equipment*
5. UI GF4 New *Fuel preparation room*
6. UI GF5 New *Appropriate location of premixed engines using fuel gas mixed with air before the turbocharger*
7. UI GF6 New *Protection against cryogenic leakage and control of hazardous zones in fuel preparation rooms on open deck*
8. UI GF7 New *External surface area of the tank for determining sizing of pressure relief valve*
9. UI GF8 New *Control and maintenance of pressure and temperature of liquefied gas fuel tanks after the activation of the safety system*
10. UI GF9 New *Special consideration within the risk assessment of closed or semi-enclosed bunkering stations*
11. UI GF10 New *Ventilation of machinery spaces*
12. UI GF11 New *Ventilation of double piping and gas valve unit spaces in gas safe engine-rooms*
13. UI GF12 New *Ventilation inlet for double wall piping or duct*
14. UI GF13 Rev.1 *Fire protection of spaces containing equipment for the fuel preparation*
15. UI GF14 New *Hazardous area classification of fuel storage hold spaces*
16. UI GF15 New *Alarms for loss of ventilation capacity*
17. UI GF16 New *Liquefied gas fuel tank loading limit higher than calculated using the reference temperature*
18. UI GF17 New *Other rooms with high fire risk*
19. UI GF18 New *Level indicator in the bilge well of tank connection spaces of independent liquefied gas storage tanks*

20. UR Z16, Rev.4, Corr.1 *Periodical surveys of cargo installations on ships carrying liquefied gases in bulk*

21. REC. 34, Rev.2 *Standard Wave Data*
22. REC. 146 New *Risk assessment as required by the IGF Code*
23. REC. 148, Rev.1 *Survey of liquefied gas fuel containment systems*

List of amendments as of 1 January 2024

Item	*Title/Subject*	*Source*
9.2.2	Fuel supply to consumers – functional requirements	MSC.1/Circ.1670
5.3.4.2	Calculation of the acceptable location of the fuel tanks (f_V)	MSC.458(101)
6.8.3	Loading limit for liquefied gas fuel tank	MSC.458(101)
9.5.3 to 9.5.6	Protection of fuel pipes	MSC.458(101)
10.3.1.1.1	Explosion relief systems for exhaust systems	MSC.458(101)
11.3.3	Separation of space containing fuel containment system by cofferdam	MSC.458(101)
11.3.3.1	Fuel storage hold considered as a cofferdam	MSC.458(101)
6.7.1.1	Pressure relief system for spaces, which may be subject to pressures beyond their design capabilities	MSC.475(102)
11.8	Fuel preparation room fire-extinguishing systems	MSC.475(102)
16.3.3.5.1	Welding procedure tensile test	MSC.475(102)
17	Requirements for ships using hydrogen as fuel (new Chapter 17)	CCC 9/WP.3
15.4.2.3	Test for gas fuel tank's high level alarm	UI GF1
11.3.1	Fire protection of spaces containing equipment for the fuel preparation	UI GF13
Annex 2	Risk assessment as required by the IGF Code (new Annex 2)	REC. 146