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CR CLASSIFICATION SOCIETY

# GUIDELINES FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS

**CR CLASSIFICATION SOCIETY**

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# GUIDELINES FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS

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# *CHAPTER 1 PREAMBLE*

Note:
CR Guidelines for Ships Using Gases or other Low-Flashpoint Fuels(hereinafter referred to as “the Guidelines”) incorporate the text in full of the “International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels”(hereinafter referred to as “the IGF Code”), as amended. The text is printed in italics as this paragraph. Classification requirements additional to the provisions of the IGF Code are presented in non-italics “Times New Roman” used for the Guidelines and the title of relevant paragraphs is added the letter (CR) or (IACS).

## 1 *Preamble*

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

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

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

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

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

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

### 1.1 (CR) Class Notations

#### 1.1.1 Gas Fuelled Ship

The **GFS** notation may be assigned where a ship is arranged to burn natural gas as fuel for propulsion or auxiliary purposes and is designed, constructed and tested in accordance with the requirements of the Guidelines. The **GFS** notation will be assigned in association with one or more of the following additional notations (e.g., **GFS(DFD, GCU**)). Upon special consideration, the equipment notations referenced below may be assigned on an individual basis for specific ship types.

#### 1.1.2 Alternative Low Flashpoint Fueled Ship

The **LFFS** notation may be assigned where a ship is arranged to burn a low flashpoint fuel other than natural gas for propulsion or auxiliary purposes and is designed, constructed and tested in accordance with the requirements of the Guidelines. The equivalence of the design is to be demonstrated by application of the

Alternative Design criteria detailed under 2.3 of the Guidelines. The **LFFS** notation will be assigned in association with the specific low flashpoint fuel and one or more of the following additional notations (e.g., **LFFS(DFD - Methanol**)).

#### 1.1.3 Reliquefaction System

Where a Reliquefaction System is designed, constructed and tested in accordance with 6.9.3 and Annex 2 of the Guidelines, the optional **RELIQ** notation will be assigned upon the Client's request.

Where the system is used to comply with 6.9.1.1.1 and 6.9.1.1.4 of the Guidelines, the **RELIQ** notation is required.

#### 1.1.4 Gas Combustion Unit

Where a Gas Combustion Unit is designed, constructed and tested in accordance with 6.9.4 and Annex 3 of the Guidelines, the optional **GCU** notation will be assigned upon the Client's request.

Where the unit is used to comply with 6.9.1.1.2 of the Guidelines, the **GCU** notation is required.

#### 1.1.5 Dual Fuel Diesel Engine Power Plant

Where a dual fuel diesel engine power plant is fitted, the **DFD** notation is required and the unit is to be designed, constructed and tested in accordance with the applicable requirements of Chapter 10 of the Guidelines.

Where a dual fuel diesel engine power plant is also designed, constructed and tested in association with 1.1.1 of the Guidelines for a low flashpoint fuel other than natural gas, the **DFD** notation will be assigned with a note relative to the particular low flashpoint fuel (e.g., **DFD - Methanol**).

#### 1.1.6 Single Gas Fuel Engine Power Plant

Where a single gas fuel engine power plant is fitted, the **SGF** notation is required and the unit is to be designed, constructed and tested in accordance with the applicable requirements of Chapter 10 of the Guidelines.

#### 1.1.7 Dual Fuel Gas Turbine Power Plant

Where a dual fuel gas turbine power plant is fitted, the **DFGT** notation is required and the unit is to be designed, constructed and tested in accordance with 10.5 of the Guidelines.

### 1.2 (CR) Certification

The certification of machinery, equipment and systems includes design review and survey carried out by CR Classification Society (hereinafter referred to as “CR”), witnessing testing, and issuance of reports or certificates by CR. Also see Part I of CR Rules for the Construction and Classification of Steel Ships (hereinafter referred to as “the Rules for Steel Ships”).

### 1.3 (CR) Format of the Guidelines

The Guidelines are based on the technical requirements of the IGF Code, which are all contained in their entirety and are required for classification.

The IGF Code takes effect on 1 January 2017 upon entry into force of amendments to Chapters II-1, II-2 and the Appendix to the Annex of SOLAS to make the provisions of the IGF Code mandatory. MSC 392(95) refers.

The Guidelines specify only the unique requirements applicable to ships using gases or other low flashpoint fuels. The Guidelines are always to be used with other relevant Parts of the Rules for Steel Ships.

The term “shall be” is to be understood to read as “must be” or “is to be” or “are to be” and unless otherwise specified, the term “Administration” is to be read as “CR”. The numbering system of the technical requirements reproduced herein follow the numbering contained in the IGF Code, except the prefix of the numbering has been modified to reflect the Guidelines.

The parts in the Guidelines which are classification requirements and not based on the IGF Code are presented in non-italics "Times New Roman" type style, etc. Under these parts are also interpretations of the IGF Code with their source such as IMO (International Maritime Organization), IACS (International Association of Classification Societies), etc., and additional CR requirements. In these parts, the term "should be" is to be understood to read as "must be" or "is to be" or "are to be".

The parts of the Guidelines which are operational, training or national requirements are presented in italic "Arial" type style (i.e., operational, training or national requirements) and are not required for classification, and are shown for information only.

The text contained in the Guidelines that come from the IGF Code is presented in italics "Times New Roman" type style.

# *CHAPTER 2 GENERAL*

Note:
The IGF Code part A is incorporated into Chapter 2 to 4 of the Guidelines.

***PART A – Cargo Containment***

## *2.1 Application*

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

(CR)
The Guidelines are to be applied to both new construction and existing ship conversions, regardless of size, including those of less than 500 gross tonnage, utilizing natural gas as fuel.

## *2.2 Definitions*

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

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

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

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

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

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

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

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

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

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

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

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

*2.2.11 Enclosed space means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.*(2)

*2.2.12 ESD means emergency shutdown.*

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

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

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

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

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

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

IACS Interpretation of 2.2.15.3

.1 A tank connection space may be required also for tanks on an open deck. This may apply to ships where the 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.

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

*Note 2:*
*See also definition in IEC 60092-502:1999*

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

IACS Interpretation of 2.2.17

A tank connection space that 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.

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

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

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

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

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

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

*2.2.24 LEL means the lower explosive limit.*

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

*2.2.26 LNG means liquefied natural gas.*

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

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

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

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

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

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

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

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

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

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

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

*2.2.38 Semi-enclosed space means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.*(3)

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

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

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

*2.2.42 Ship constructed on or after 1 January 2024 means:*

*.1 for which the building contract is placed on or after 1 January 2024; or*

*.2 in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 July 2024; or*

*.3 the delivery of which is on or after 1 January 2028.*

2.2.43 (CR) Gas Combustion Unit(GCU)

"Gas Combustion Unit" (or "Thermal Oxidizer") means a system used for controlling the pressure in the LNG storage tanks by burning the excess boil-off gas(BOG) from the tanks inside an enclosed combustion chamber under controlled and safe conditions.

*Note 3:*
*Refer also to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features*

2.2.44 (CR) Hazardous areas

See also 12.5 for further guidance.

Hazardous areas are divided into zones 0, 1 and 2 as defined below:

.1 Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods or frequently.

.2 Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation occasionally.

.3 Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

2.2.45 (CR) IGC Code

"IGC Code" means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

2.2.46 (CR) Master Gas Fuel Valve

"Master Valve", "Master Gas Valve", or "Master Gas Fuel Valve" means an automatic shut-off valve in the fuel gas supply line to each consumer and which is located outside the machinery space of the consumer.

2.2.47 (CR) Natural Gas

"Natural Gas" (dry) is defined as gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane). The gas composition can vary depending on the source of natural gas and the processing of the gas.

The gas may be stored and distributed as CNG or LNG.

2.2.48 (CR) Pre-mixed Gas Fuel Engines

"Pre-mixed Gas Fuel Engines" are gas or dual fuel engines where the gas is introduced into the combustion air flow before it enters the cylinder or cylinder head port. For example, before the turbocharger.

2.2.49 (CR) Primary Barrier

"Primary Barrier" is the inner element designed to contain the fuel when the fuel containment system includes two boundaries.

2.2.50 (CR) Recognized Standard

A "Recognized Standard" is an international or national standard acceptable to the Society.

## *2.3 Alternative Design*

*2.3.1 The IGF Code contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels*

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

*.1 deviate from those set out in the IGF Code, or*

*.2 be designed for use of a fuel not specifically addressed in the IGF Code.*

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

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

(CR)
Where prescriptive IMO requirements exist for particular gases or other low flashpoint fuels, either by regulation, or as interim guidelines, these may be applied, subject to agreement by the Flag Administration, in lieu of the Alternative Design criteria (e.g., MSC.1/Circ.1621, the Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuels).

# *CHAPTER 3 GOAL AND FUNCTIONAL REQUIREMENTS*

## *3.1 Goal*

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

## *3.2 Functional Requirements*

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

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

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

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

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

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

*3.2.7 System components shall be protected against external damages.*

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

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

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

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

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

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

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

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

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

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

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

# *CHAPTER 4 GENERAL REQUIREMENTS*

## *4.1 Goal*

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

## *4.2 Risk Assessment*

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

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

(CR)
For alternative designs permitted by 2.3 of the Guidelines, a more detailed risk assessment covering the alternative design will be required.

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

## *4.3 Limitation of Explosion Consequences*

*An explosion in any space containing any potential sources of release(4) and potential ignition sources shall not:*

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

*.2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;*

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

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

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

*.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.*

# *CHAPTER 5 SHIP DESIGN AND ARRANGEMENT*

Note:
The IGF Code Part A-1 is incorporated into Chapter 5 to 15 of the Guidelines.

*PART A-1 – Specific Requirements for Ships Using Natural Gas as Fuel*

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

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

## *5.1 Goal*

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

(CR) Plans and data to be submitted
Plans and specifications covering the ship arrangements and systems listed below are to be submitted, and are, as applicable, to include:

.1 Risk assessment as referenced by 4.2 of the Guidelines

.2 General arrangement

.3 Fuel storage arrangements

.4 Fuel supply system arrangements

.5 Fuel bunkering station arrangements

.6 Hazardous area classification plan

.7 Vent mast and venting arrangements

## *5.2 Functional Requirements*

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

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

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

.3 *the access or other openings to spaces containing fuel sources of release shall be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;*

.4 *fuel piping shall be protected against mechanical damage;*

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

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

## *5.3 Regulations – General*

*5.3.1 Fuel storage tanks shall be protected against mechanical damage.*

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

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

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

*where:*

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

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

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

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

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

.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* $m^3 \le V_c < 30,000\ m^3$*, 0.8 +* $V_c/25,000$ *m; and*

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

*Where:*

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

.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 2.3 of the Guidelines.*

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

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

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

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

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

*Note 5:*
*The value* $f_{CN}$ *accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.Where:*

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

$$f_t = 1 - r(x_1, x_2, b)^{(6)}$$

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

*$f_v = 1.0 - 0.8 \cdot ((H - d)7.8)$, if $(H - d)$ is less than or equal to 7.8 m. $f_v$ shall not be taken greater than 1.*
*$f_v = 0.2 - 0.2 \cdot ((H - d) - 7.8)/4.7)$, in all other cases $f_v$ shall not be taken less than 0.*

*Where:*

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

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

.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 of the Guidelines.*

.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 $m^3 \le V_c <$ 30,000 $m^3$, $0.8 + V_c/25{,}000$ m; and*

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

*Where:*

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

.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 above 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.*

*Note 6:*
*When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline the value of b should be taken as 0.*

*.7 In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of $f_{CN}$ shall be calculated on both starboard and port side and the average value shall be used for the assessment. The minimum distance as set forth in paragraph 5.3.4.5 above 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 2.3 of the Guidelines.*

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

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

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

5.3.6 (CR)
Access to the fuel containment system and hull structure for the purpose of inspection, evacuation and maintenance is to be in accordance with 28.2.5 of Part II of the Rules for Steel Ships, as applicable.

## *5.4 Machinery Space Concepts*

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

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

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

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

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

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

IACS Interpretation of 5.4.1
Premixed engines using fuel gas mixed with air before the turbocharger should be located in ESD protected machinery spaces.

## *5.5 Regulations for Gas Safe Machinery Space*

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

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

## *5.6 Regulations for ESD-Protected Machinery Spaces*

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

(CR)
Machinery spaces certified for periodically unattended operation, are to be arranged in accordance with the requirements for **CAU** Symbol, as per Chapter 5 of Part VIII of the Rules for Steel Ships.

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

*.1 gas detector;*

*.2 shutoff valve;*

*.3 redundancy; and*

*.4 efficient ventilation.*

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

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

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

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

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

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

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

CR Interpretation of 5.6.6
ESD protected machinery spaces/enclosures are also to be as small in volume as practicable, without compromising maintainability, in order to facilitate effective ventilation and gas detection.

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

5.6.8 (CR)
Each engine installed in an ESD-protected machinery space is to have a separately ducted combustion air intake system.

## *5.7 Regulations for Location and Protection of Fuel Piping*

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

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

CR Interpretation of 5.7.2
Fuel piping in the Guidelines are to be understood to include fuel vent piping from tank pressure relief valves, block and bleed valves and relief valves or vent lines from other fuel gas supply system components and fuel consumers.

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

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

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

## *5.8 Regulations for Fuel Preparation Room Design*

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

CR Interpretation of 5.8
The IGF Code already includes detailed requirements for fuel preparation rooms when located below deck. The specific regulations for tank connection spaces which are to be applied to fuel preparation rooms located below deck are as per 6.7.1.1. of the Guidelines.

IACS Interpretation of 5.8

.1 Fuel preparation rooms, regardless of location, should be arranged to safely contain cryogenic leakages.

.2 The material of the boundaries of the fuel preparation room should 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 should 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 should 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.

## *5.9 Regulations for Bilge Systems*

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

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

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

## *5.10 Regulations for Drip Trays*

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

(CR)

Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections or pump seals, protection for the hull beneath is to be provided.

*5.10.2 Drip trays shall be made of suitable material.*

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

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

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

5.10.6 (CR)

The drip trays located below the tank connections and other sources of vapor release from the tanks are to be located not less than 3 m from entrances, air inlets and openings to accommodation spaces, services spaces, cargo spaces, machinery spaces and control stations.

5.10.7 (CR)

Type C LNG storage tanks applying the safety principles and arrangements of the “tank connection space” detailed in the Guidelines may be accepted for installation on open deck without drip trays.

## *5.11 Regulations for Arrangement of Entrances and Other Openings in Enclosed Spaces*

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

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

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

(CR)
Access to the tank connection space is, as far as practicable, to be independent and direct from the open deck. The dimensions of horizontal and vertical openings are to be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be not less than 600 mm × 600 mm for horizontal openings and for vertical openings not less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided. Arrangements are to be such that it is not possible to have unauthorized access to the tank connection space during normal operation of the gas system. If access is not direct from the open deck, such access is to be arranged as a bolted hatch and the space containing the bolted hatch will be a hazardous zone 2, as required in 12.5.3.2 of the Guidelines.

*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 of the Guidelines.*

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

## *5.12 Regulations for Airlocks*

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

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

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

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

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

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

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

# CHAPTER 6 FUEL CONTAINMENT SYSTEM

## 6.1 Goal

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

(CR) Plans and data to be submitted

The following plans, calculations and information, as appropriate, are to be submitted in addition to those required by Part I of the Rules for Steel Ships:

.1 General arrangement plans of the ship showing the position of the fuel containment system and details of manholes and other openings in fuel tanks.

.2 Plans of the hull structure in way of the fuel tanks, including the installation of attachments, accessories, internal reinforcements, saddles for support and tie-down devices.

.3 Plans of the structure of the fuel containment system, including the installation of attachments, supports and attachment of accessories.

For independent pressure fuel tanks, the standard or Code adopted for the construction and design is to be identified. Detailed construction drawings together with design calculations for the pressure boundary, tank support arrangement and analysis for the load distribution. Anti-collision, chocking arrangement and design calculations.

.4 Distribution of the specification, grades and types of steel proposed for the structures of the hull and of the fuel containment system, including attachments, valves, accessories, etc., together with the calculation of the temperatures on all of the structures which can be affected by the low temperatures of the fuel.

.5 Design loads and structural analyses for the fuel storage tank(s) together with complete stress analysis, as applicable, of the hull and fuel containment system including sloshing analysis.

.6 Specifications and plans of the insulation system and calculation of the heat balance.

.7 Procedures and calculations of the cooling down and loading operations, including loading limit curve.

.8 Loading and unloading systems, venting systems, and gas-freeing systems, as well as a schematic diagram of the remote controlled valve system.

.9 Details and installation of the safety valves and relevant calculations of their relieving capacity, including back pressure.

.10 Fuel tank pressure accumulation calculation.

.11 Details and installation of the various monitoring and control systems, including the devices for measuring the level of the fuel in the tanks and the temperatures in the containment system.

.12 Schematic diagram of the ventilation system indicating the vent pipe sizes and location of the openings.

.13 Schematic diagram of the refrigeration system together with the calculations concerning the refrigerating capacity.

.14 Details of the electrical equipment installed in the fuel containment area and of the electrical bonding of the fuel tanks and piping.

.15 Details of testing procedures of fuel tanks and liquid and vapor systems.

.16 Diagram of inert-gas system or hold-space environmental-control system.

.17 Diagram of gas-detection system.

.18 Schematic-wiring diagrams.

.19 Details of all fuel and vapor handling equipment.

.20 Details of fire extinguishing systems.

.21 Welding procedures, stress relieving and non-destructive testing plans.

.22 Construction details of submerged fuel pumps including materials specifications.

.23 Operating and maintenance instruction manuals, see 6.7.2.6, 6.3.12, 18.2.2 to 18.2.4 and 18.4.2.1 of the Guidelines. To be submitted for reference purposes only.

## *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 of the Guidelines. 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; see IACS Interpretation of 5.8 of the Guidelines;*

*.2 flammable fuels spreading to locations with ignition sources;*

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

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

*.5 reduction in availability of LSA.*

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

*.3 the fuel containment arrangement shall be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and*

*.4 if portable tanks are used for fuel storage, the design of the fuel containment system shall be equivalent to permanent installed tanks as described in this chapter.*

## *6.3 Regulations – General*

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

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

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

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

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

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

*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.*

CR Interpretation of 6.3.7

The tank connection space is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling in case of leakage of the liquid or compressed gas.

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

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

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

CR Interpretation of 6.3.10

Connections to fuel gas storage tanks and piping containing pressurized LNG other than those in tank connection spaces are to be provided with spray shields and drip trays at potential leak points such as flanged joints and valves.

IACS Interpretation of 6.3.10

.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.

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

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

## *6.4 Regulations for Liquefied Gas Fuel Containment*

### *6.4.1 General*

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

CR Interpretation of 6.4.1.1

The evaluation of the ship’s liquefied gas fuel containment system as part of the risk assessment required by 6.4.1.1 above need only be undertaken for novel fuel containment system arrangements not prescriptively covered by this Chapter, or where unusual fuel containment system location is proposed. An example of this is fuel tanks located adjacent to or underneath accommodation, whereby it is expected that the risk assessment would cover such subjects as, but not limited to, protective location, fire protection, lifesaving appliance equipment and evacuation arrangements.

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

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

*6.4.1.4 Liquefied gas fuel containment systems shall be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Less demanding environmental conditions, consistent with the expected usage, may be accepted by the Administration for liquefied gas fuel containment systems used exclusively for restricted navigation. More demanding environmental conditions may be required for liquefied gas fuel containment systems operated in conditions more severe than the North Atlantic environment.*[7],[8] *6.4.1.5 Liquefied gas fuel containment systems shall be designed with suitable safety margins:*

*.1 to withstand, in the intact condition, the environmental conditions anticipated for the liquefied gas fuel containment system's design life and the loading conditions appropriate for them, which shall include full homogeneous and partial load conditions and partial filling to any intermediate levels; and*

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

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

*.1 Collision – The liquefied gas fuel containment system shall withstand the collision loads specified in 6.4.9.5.1 of the Guidelines 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 of the Guidelines 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 of the Guidelines 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.*

*Note 7:*
*Refer to IACS Rec.034.*

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

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

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

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

*6.4.2 Liquefied gas fuel containment safety principles*

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

*6.4.2.2 The size and configuration or arrangement of the secondary barrier may be reduced or omitted where an equivalent level of safety can be demonstrated in accordance with 6.4.2.3 to 6.4.2.5 below as applicable.*

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

*The arrangements shall comply with the following:*

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

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

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

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

*6.4.3 Secondary barriers in relation to tank types*

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

| ***Basic tank type*** | ***Secondary barrier*** |
|---|---|
| *Membrane* | *Complete secondary barrier* |
| *Independent:* | |
| *Type A* | *Complete secondary barrier* |
| *Type B* | *Partial secondary barrier* |
| *Type C* | *No secondary barrier* |

*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 of the Guidelines;*

*.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 above 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°.*

CR Interpretation of 6.4.4.6

Extent of complete secondary barrier.

The extent of the complete secondary barrier is to be not less than that obtained assuming the fuel tank is breached at a static angle of heel of 30° and there is an equalization of liquid in the hold space. See Figure 6-1 of the Guidelines.

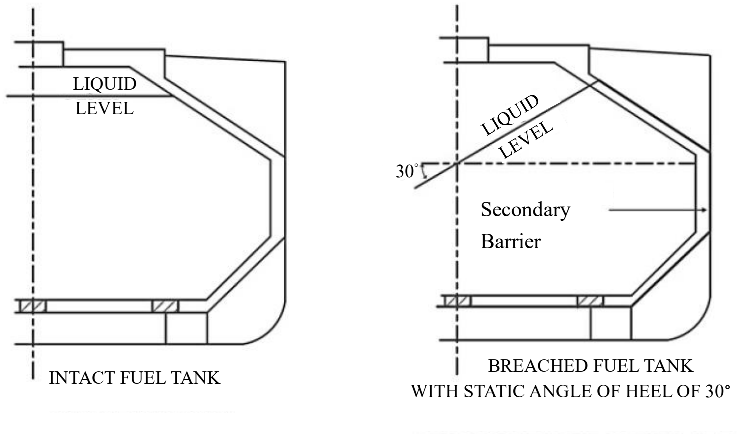



**Figure 6-1**

*6.4.5 Partial secondary barriers and primary barrier small leak protection system*

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

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

*6.4.5.2 The capacity of the partial secondary barrier shall be determined, based on the liquefied gas fuel leakage corresponding to the extent of failure resulting from the load spectrum referred to in 6.4.12.2.6 of the Guidelines, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.*

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

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

*6.4.6 Supporting arrangements*

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

CR Interpretation of 6.4.6.1(permissible stress in way of supports of type C fuel tanks)

.1 With reference to 6.4.6.1 above, the following criterion for the allowable stresses in way of supports of type C-fuel tanks made of carbon manganese steel may be used:

$$\sigma_e = \sqrt{(\sigma_n + \sigma_b) + 3\tau^2} \leq \sigma_a$$

Where:

$\sigma_e$ = equivalent stress (N/mm$^2$)

$\sigma_n$ = normal stress in the circumferential direction of the stiffening ring (N/mm$^2$)

$\sigma_b$ = bending stress in the circumferential direction of the stiffening ring (N/mm$^2$)

$\tau$ = shear stress in the stiffening ring (N/mm$^2$)

$\sigma_a$ = allowable stress (N/mm$^2$), to be taken as the smaller of the values: 0.57 $R_m$ or 0.85 $R_e$

$R_m$ and $R_e$, as defined in 6.4.12.1.1.3.1 and 6.4.12.1.1.3.2 of the Guidelines.

Equivalent stress values $\sigma_e$ should be calculated over the full extent of the stiffening ring by a procedure acceptable to the Society, for a sufficient number of load cases, as defined in 6.4.9.3 of the Guidelines.

.2 The following assumptions should be made for the stiffening rings:

.1 The stiffening ring should be considered as a circumferential beam formed by web, face plate, doubler plate, if any, and associated shell plating.
The effective width of the associated plating should be taken as:

.1 For cylindrical shells: an effective width (mm) not greater than $0.78\sqrt{rt}$ on each side of the web. A doubler plate, if any, may be included within that distance.

where:

r = mean radius of the cylindrical shell (mm)

t = shell thickness (mm).

.2 For longitudinal bulkheads (in the case of lobe tanks): the effective width should be determined according to established standards. A value of $20t_b$ on each side of the web may be taken as a guidance value.

where:

$t_b$ = bulkhead thickness (mm).

.2 The stiffening ring should be loaded with circumferential forces, on each side of the ring, due to the shear stress, determined by the bi-dimensional shear flow theory from the shear force of the tank.

.3 .1 Elasticity of support material (intermediate layer of wood or similar material)

.2 Change in contact surface between tank and support, and of the relevant reactions, due to:

- thermal shrinkage of tank
- elastic deformations of tank and support material.

The final distribution of the reaction forces at the supports should not show any tensile forces.

.4 The bucking strength of the stiffening rings should be examined.

*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 of the Guidelines without plastic deformation likely to endanger the hull structure.*

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

*6.4.7 Associated structure and equipment*

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

*6.4.8 Thermal insulation*

*6.4.8.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable (see 6.4.13.1.1 of the Guidelines) 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 of the Guidelines.*

*6.4.9 Design loads*

*6.4.9.1 General*

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

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

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

*6.4.9.2 Permanent loads*

*6.4.9.2.1 Gravity loads*

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

*6.4.9.2.2 Permanent external loads*

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

*6.4.9.3 Functional loads*

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

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

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

*(a) internal pressure*
*(b) external pressure*
*(c) thermally induced loads*
*(d) vibration*
*(e) interaction loads*
*(f) loads associated with construction and installation*
*(g) test loads*
*(h) static heel loads*
*(i) weight of liquefied gas fuel*
*(j) sloshing*
*(k) wind impact, wave impacts and green sea effect for tanks installed on open deck.*

*6.4.9.3.3.1 Internal pressure*

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

*.2 For liquefied gas fuel tanks where there is no temperature control and where the pressure of the liquefied gas fuel is dictated only by the ambient temperature, $P_0$ shall not be less than the gauge vapour pressure of the liquefied gas fuel at a temperature of 45℃ 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 of the Guidelines 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:*

$$P_{eq1} = P_0 + (P_{gd})max\ (MPa),$$
$$P_{eq2} = P_h + (P_{gd\,site})max\ (MPa).$$

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

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

*where:*

$\alpha_\beta$ = *dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction $\beta$; (see Figure 6-2 below).*

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

$Z_\beta$ = *largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the $\beta$ direction (see Figure 6-3 below).*

*Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining $Z_\beta$ 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 of the Guidelines.*

$\rho$ = *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 6-2 below. The above formula applies only to full tanks.*

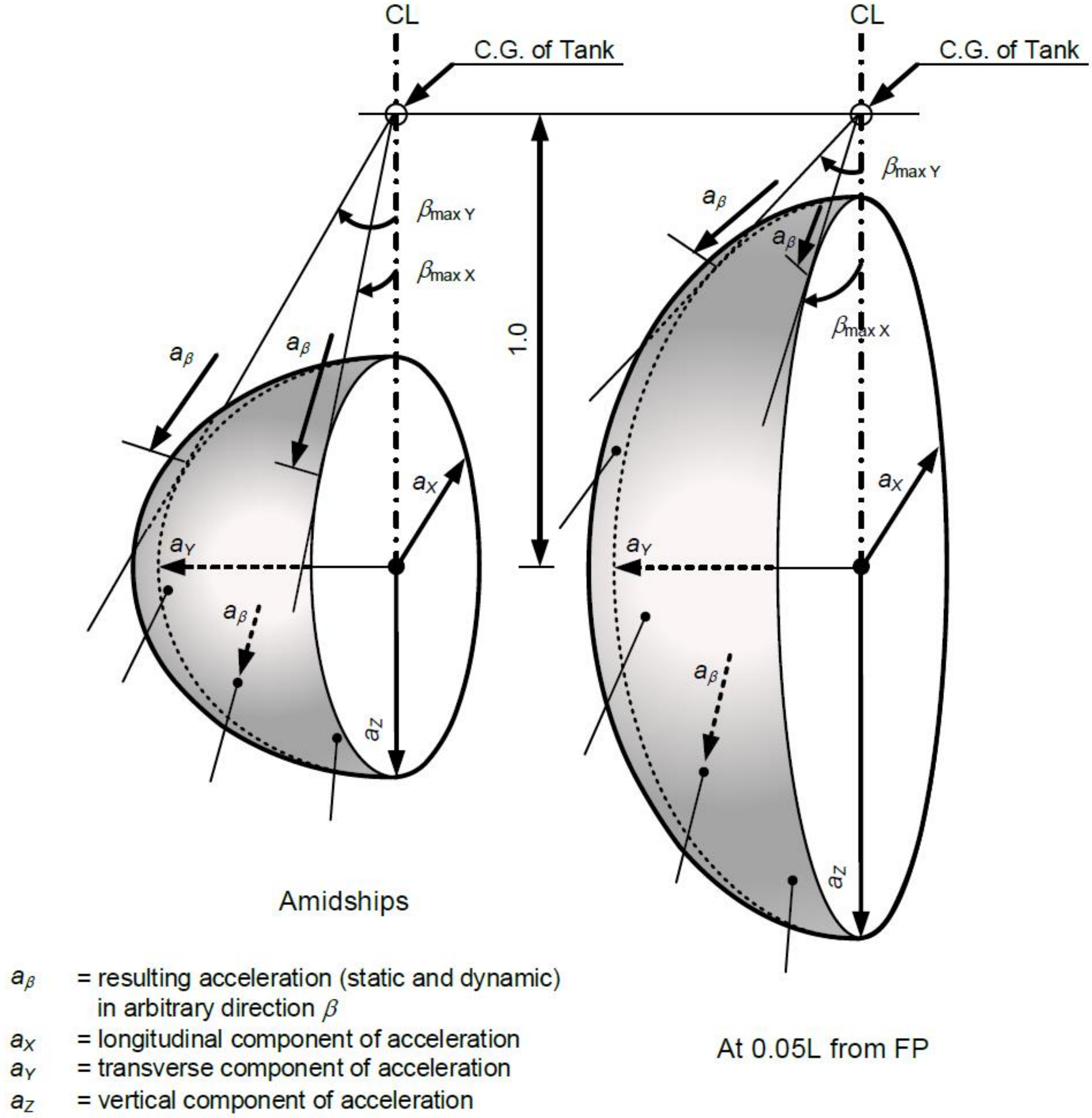



***Figure 6-2***
***Acceleration Ellipsoid***

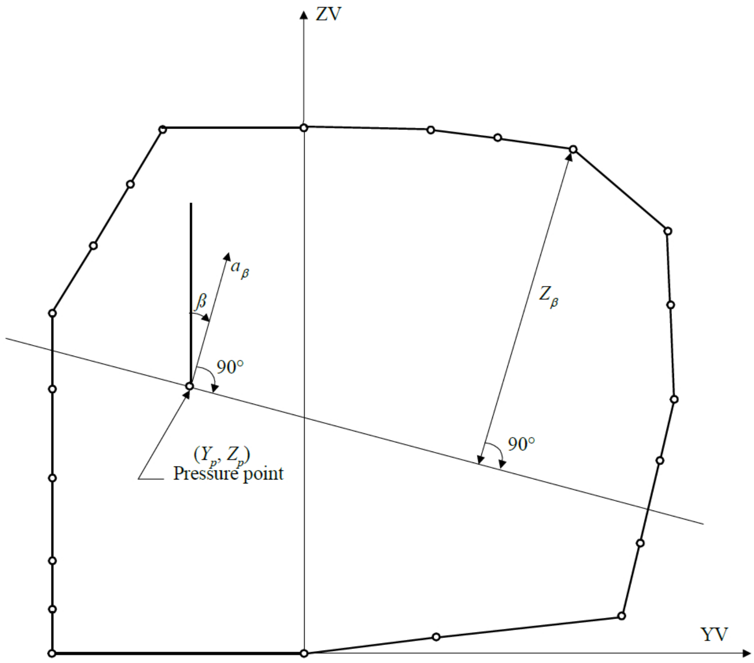



***Figure 6-3***
***Determination of Internal Pressure Heads***

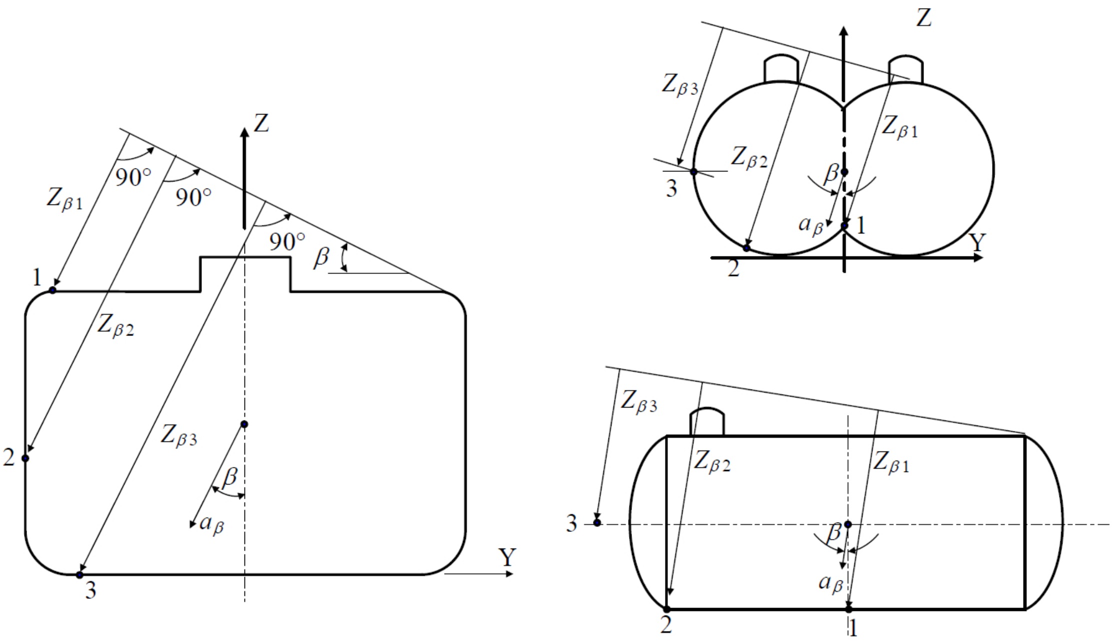



**Figure 6-4**
**Determination of Liquid Height $Z_\beta$ for Points 1, 2 and 3**

*6.4.9.3.3.2 External pressure*

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

*6.4.9.3.3.3 Thermally induced loads*

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

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

*6.4.9.3.3.4 Vibration*

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

*6.4.9.3.3.5 Interaction loads*

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

*6.4.9.3.3.6 Loads associated with construction and installation*

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

*6.4.9.3.3.7 Test loads*

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

*6.4.9.3.3.8 Static heel loads*

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

*6.4.9.3.3.9 Other loads*

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

*6.4.9.4 Environmental loads*

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

*6.4.9.4.1.1 Loads due to ship motion*

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

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

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

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

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

*Ships for restricted service may be given special consideration.*

*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.*

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

*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.*

(CR)

Fuel tanks are to be designed for the complete range of fill conditions up to 98% full. Accordingly, calculations or model test are required to show that the resulting loads and pressures for all fill levels are within acceptable limits for the scantlings of the tanks.

*6.4.9.4.1.4 Snow and ice loads*

*Snow and icing shall be considered, if relevant.*

*6.4.9.4.1.5 Loads due to navigation in ice*

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

*6.4.9.4.1.6 Green sea loading*

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

*6.4.9.4.1.7 Wind loads*

*Account shall be taken to wind generated loads as relevant.*

*6.4.9.5 Accidental loads*

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

*6.4.9.5.1 Collision load*

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

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

*Special consideration should be given to ships with Froude number (Fn) > 0.4.*

*6.4.9.5.2 Loads due to flooding on ship*

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

*6.4.10 Structural integrity*

*6.4.10.1 General*

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

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

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

*6.4.11 Structural analysis*

*6.4.11.1 Analysis*

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

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

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

*6.4.11.2 Load scenarios*

*6.4.11.2.1 For each location or part of the liquefied gas fuel containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.*

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

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

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

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

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

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

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

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

*Where:*

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

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

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

*6.4.12 Design conditions*

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

*6.4.12.1 Ultimate design condition*

*6.4.12.1.1 Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of the IGF 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 $\sigma_c$ (von Mises, Huber) shall be determined by:*

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

*where:*

$\sigma_x$ = *total normal stress in x-direction;*

$\sigma_y$ = *total normal stress in y-direction;*

$\sigma_z$ = *total normal stress in z-direction;*

$\tau_{xy}$ = *total shear stress in x-y plane;*

$\tau_{xz}$ = *total shear stress in x-z plane; and*

$\tau_{yz}$ = *total shear stress in y-z plane.*

*The above values shall be calculated as described in 6.4.11.2.3 of the Guidelines.*

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

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

*6.4.12.2 Fatigue Design Condition*

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

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

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

*where:*

| | | |
|---|---|---|
| $n_i$ | = | *number of stress cycles at each stress level during the life of the tank;* |
| $N_i$ | = | *number of cycles to fracture for the respective stress level according to the Wohler (S-N) curve;* |
| $n_{Loading}$ | = | *number of loading and unloading cycles during the life of the tank not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle;* |
| $N_{Loading}$ | = | *number of cycles to fracture for the fatigue loads due to loading and unloading; and* |
| $C_w$ | = | *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-2-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable $C_w$ values specified in 6.4.12.2.7 to 6.4.12.2.9 of the Guidelines.*

.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 of the Guidelines, 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 of the Guidelines, 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 below the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in Figure 6-5 below. Load distribution and sequence for longer periods, such as in 6.4.12.2.8 and 6.4.12.2.9 below shall be approved by the Administration.*

*The arrangements shall comply with 6.4.12.2.7 to 6.4.12.2.9 below 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:*

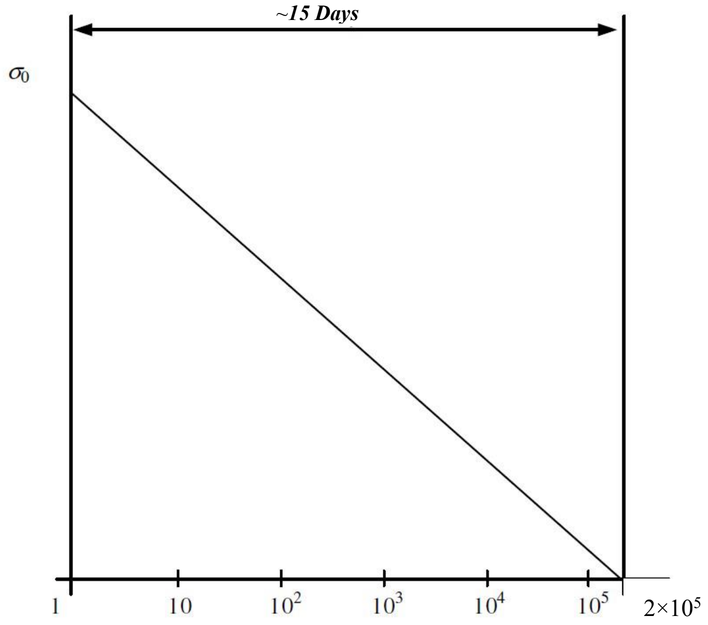
$C_w$ *shall be less than or equal to 0.5.*

*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 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 3 times the lifetime of the tank.*




*Response Cycles*

$\sigma_0$ *= most probable maximum stress over the life of the ship*

*Note: Response cycles scale is logarithmic, the value of* $2\times10^5$ *is given as an example of estimate*

***Figure 6-5***
***Simplified Load Distribution***

6.4.12.3 *Accidental design condition*

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

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

| | |
|---|---|
| *Permanent loads* ∶ | *Expected values* |
| *Functional loads* ∶ | *Specified values* |
| *Environmental loads* ∶ | *Specified values* |
| *Accidental loads* ∶ | *Specified values or expected values* |

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

### *6.4.13 Materials and construction*

#### *6.4.13.1 Materials*

##### *6.4.13.1.1 Materials forming ship structure*

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

*.1 The primary barrier of all tanks shall be assumed to be at the liquefied gas fuel temperature.*

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

*.3 For worldwide service, ambient temperatures shall be taken as 5℃ for air and 0℃ 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 of the Guidelines shall be assumed.*

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

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

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

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

*6.4.13.1.1.2 The materials of all hull structures for which the calculated temperature in the design condition is below 0℃, due to the influence of liquefied gas fuel temperature, shall be in accordance with Table7-5 of the Guidelines. This includes hull structure supporting the liquefied gas fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.*

*6.4.13.1.1.3 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Table7-5 of the Guidelines. In the calculations required in 6.4.13.1.1.1 above, 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 above 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 above, for longitudinal bulkhead between liquefied gas fuel tanks, credit may be taken for heating provided the material remain suitable for a minimum design temperature of – 30°C, or a temperature 30°C lower than that determined by 6.4.13.1.1.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.*

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

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

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

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

CR Interpretation of 6.4.13.1.1.4

Where the fuel is carried in a containment system requiring a secondary barrier, the hull heating system is to be contained solely within the fuel storage area or the drain returns from the hull heating coils, cofferdams, and double bottom are to be led to a degassing tank. The degassing tank is to be located in the fuel storage area, where possible, and the vent outlets are to be located in a safe position and fitted with a flame screen.

*6.4.13.2 Materials of primary and secondary barriers*

*6.4.13.2.1 Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with Tables 7-1, 7-2 or 7-3 of the Guidelines.*

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

*6.4.13.2.3 Where non-metallic materials,(10) including composites, are used for or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:*

.1 *compatibility with the liquefied gas fuels;*

.2 *ageing;*

.3 *mechanical properties;*

.4 *thermal expansion and contraction;*

.5 *abrasion;*

.6 *cohesion;*

.7 *resistance to vibrations;*

.8 *resistance to fire and flame spread; and*

.9 *resistance to fatigue failure and crack propagation.*

*6.4.13.2.4 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than –196°C.*

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

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

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

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

*Note 10:*
*Refer to 6.4.16 of the Guidelines.*

*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.*

*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℃ below the minimum design temperature, but not lower than – 196℃.*

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

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

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

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

### *6.4.14 Construction processes*

#### *6.4.14.1 Weld joint design*

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

*6.4.14.1.2 Welding joint details for type C independent tanks, and for the liquid-tight primary barriers of type B independent tanks primarily constructed of curved surfaces, shall be as follows:*

*.1 All longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels.[11] Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure. For connections of tank shell to a longitudinal bulkhead of type C bilobe tanks, tee welds of the full penetration type may be accepted.*

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

*6.4.14.2 Design for gluing and other joining processes*

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

*6.4.15 Tank types*

*6.4.15.1 Type A independent tanks*

*6.4.15.1.1 Design basis*

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

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

*6.4.15.1.2 Structural analysis*

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

*6.4.15.1.2.2 For parts, such as structure in way of supports, not otherwise covered by the regulations in the IGF 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 of the Guidelines as far as applicable, and the ship deflection in way of supports.*

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

*Note 11:*

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

*6.4.15.1.3 Ultimate design condition*

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

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

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

*6.4.15.1.4 Accidental design condition*

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

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

*6.4.15.2 Type B independent tanks*

*6.4.15.2.1 Design basis*

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

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

*6.4.15.2.2 Structural analysis*

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

*.1 plastic deformation;*

*.2 buckling;*

*.3 fatigue failure; and*

*.4 crack propagation.*

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

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

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

*6.4.15.2.3 Ultimate design condition*

*6.4.15.2.3.1 Plastic deformation.*

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

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

*where:*

$\sigma_m$ = *equivalent primary general membrane stress*

$\sigma_L$ = *equivalent primary local membrane stress*

$\sigma_b$ = *equivalent primary bending stress*

$\sigma_g$ = *equivalent secondary stress*

$f$ = *the lesser of* $R_m/A$ *or* $R_e/B$

$F$ = *the lesser of* $R_m/C$ *or* $R_e/D$

*with* $R_m$ *and* $R_e$ *as defined in 6.4.12.1.1.3 of the Guidelines. With regard to the stresses* $\sigma_m, \sigma_L, \sigma_g$ *and* $\sigma_b$ *see also the definition of stress categories in 6.4.15.2.3.6 of the Guidelines.*

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

| | *Nickel steels and carbon manganese steels* | *Austenitic Steel* | *Aluminium Alloys* |
|---|---|---|---|
| *A* | *3* | *3.5* | *4* |
| *B* | *2* | *1.6* | *1.5* |
| *C* | *3* | *3* | *3* |
| *D* | *1.5* | *1.5* | *1.5* |

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

*.1 for nickel steels and carbon-manganese steels, the lesser of* $R_m/2$ *or* $R_e/1.2$*;*

*.2 for austenitic steels, the lesser of* $R_m/2.5$ *or* $R_e/1.2$*; and*

*.3 for aluminium alloys, the lesser of* $R_m/2.5$ *or* $R_e/1.2$*.*

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

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

*6.4.15.2.3.2 Buckling*

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

*6.4.15.2.3.3 Fatigue design condition*

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

*6.4.15.2.3.3.2 Fatigue analysis shall consider construction tolerances.*

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

*6.4.15.2.3.4 Accidental design condition*

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

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

*6.4.15.2.3.5 Marking*

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

*6.4.15.2.3.6 Stress categories*

*For the purpose of stress evaluation, stress categories are defined in this Chapter 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:*

$S_1 \leq 0.5\sqrt{Rt}$ *; and*

$S_2 \geq 2.5\sqrt{Rt}$

*Where:*

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

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

$R$ = *mean radius of the vessel;*

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

$f$ = *allowable primary general membrane stress.*

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

*6.4.15.3 Type C independent tanks*

*6.4.15.3.1 Design basis*

(CR)

The following requirements for type C independent tanks may also apply to process pressure vessels in the fuel gas supply system or reliquefaction plant, as applicable. If so required, the term "pressure vessels" covers both type C independent tanks and process pressure vessels.

*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 below is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.*

*6.4.15.3.1.2 The design vapour pressure shall not be less than:*

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

*Where:*

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

*With:*

$\sigma_m$ = *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/mm$^2$ for aluminium alloy (5083-O);*

$C$ = *a characteristic tank dimension to be taken as the greatest of the following: h, 0.75b or 0.45ℓ,*

*With:*

$h$ = *height of tank (dimension in ship's vertical direction) (m);*

$b$ = *width of tank (dimension in ship's transverse direction) (m);*

$\ell$ = *length of tank (dimension in ship's longitudinal direction) (m);*

$\rho_r$ = *the relative density of the cargo ($\rho_r$ = 1 for fresh water) at the design temperature*

*6.4.15.3.2 Shell thickness*

*6.4.15.3.2.1 In considering the shell thickness the following apply:*

*.1 for pressure vessels, the thickness calculated according to 6.4.15.3.2.4 of the Guidelines 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 of the Guidelines shall be 0.95 when the inspection and the non-destructive testing referred to in 16.3.6.4 of the Guidelines 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 of the Guidelines, depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 shall be*

*adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.*

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

*6.4.15.3.2.3 The design external pressure $P_e$, used for verifying the buckling of the pressure vessels, shall not be less than that given by:*

$$P_e = P_1+P_2+P_3+P_4 \ (MPa)$$

*where:*

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

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

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

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

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

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

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

*.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 of the Guidelines 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.*

CR Interpretation of 6.4.15.3.2.5
"Special cases" where fatigue analysis may be required by CR include, but are not limited to, novel designs and designs where cyclic loading is determined to be a factor by the design code used.

*6.4.15.3.3 Ultimate design condition*

*6.4.15.3.3.1 Plastic deformation*

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

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

where:

$\sigma_m$ = *equivalent primary general membrane stress;*
$\sigma_L$ = *equivalent primary local membrane stress;*
$\sigma_b$ = *equivalent primary bending stress;*
$\sigma_g$ = *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 of the Guidelines. With regard to the stresses* $\sigma_m$, $\sigma_L$, $\sigma_g$ *and* $\sigma_b$ *see also the definition of stress categories in 6.4.15.2.3.6 of the Guidelines. The values A and B shall have at least the following minimum values:*

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

*6.4.15.3.3.2 Buckling criteria shall be as follows:*
*The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.*

*6.4.15.3.4 Fatigue design condition*

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

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

*6.4.15.3.5 Accidental design condition*

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

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

*6.4.15.3.6 Marking*

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

*6.4.15.4 Membrane tanks*

*6.4.15.4.1 Design basis*

*6.4.15.4.1.1 The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.*

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

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

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

*6.4.15.4.1.5 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.*

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

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

*6.4.15.4.2 Design considerations*

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

*.1 Ultimate design events:*

*.1 tensile failure of membranes;*

*.2 compressive collapse of thermal insulation;*

*.3 thermal ageing;*

*.4 loss of attachment between thermal insulation and hull structure;*

*.5 loss of attachment of membranes to thermal insulation system;*

*.6 structural integrity of internal structures and their associated supporting structures; and*

*.7 failure of the supporting hull structure.*

*.2 Fatigue design events:*

*.1 fatigue of membranes including joints and attachments to hull structure;*

*.2 fatigue cracking of thermal insulation;*

*.3 fatigue of internal structures and their associated supporting structures; and*

*.4 fatigue cracking of inner hull leading to ballast water ingress.*

*.3 Accident design events:*

*.1 accidental mechanical damage (such as dropped objects inside the tank while in service);*

*.2 accidental over pressurization of thermal insulation spaces;*

*.3 accidental vacuum in the tank; and*

*.4 water ingress through the inner hull structure.*

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

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

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

*6.4.15.4.4 Structural analyses*

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

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

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

*6.4.15.4.5 Ultimate design condition*

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

*6.4.15.4.5.2 The choice of strength acceptance criteria for the failure modes of the liquefied gas fuel containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.*

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

*6.4.15.4.6 Fatigue design condition*

*6.4.15.4.6.1 Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.*

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

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

*.2 availability for inspection.*

*6.4.15.4.6.3 For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, $C_w$ shall be less than or equal to 0.5.*

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

*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 of the Guidelines.*

*6.4.15.4.7 Accidental design condition*

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

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

### *6.4.16 Limit state design for novel concepts*

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

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

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

*.1 Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.*

*.2 Fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.*

*.3 Accident limit states (ALS), which concern the ability of the structure to resist accidental situations.*

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

## *6.5 Regulations for Portable Liquefied Gas Fuel Tanks*

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

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

*.1 mechanical protection of the tanks depending on location and cargo operations;*

*.2 if located on open deck: spill protection and water spray systems for cooling; and*

*.3 if located in an enclosed space: the space is to be considered as a tank connection space.*

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

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

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

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

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

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

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

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

*.1 with the exception of the pressure relief system in 6.5.6 above 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 of the Guidelines.*

6.5.11 (CR)

The deck and any structure under or near to the portable tank connection hoses is to be protected from potential leakage by the provision of adequate drip trays and spray shields.

## *6.6 Regulations for CNG Fuel Containment*

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

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

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

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

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

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

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

## *6.7 Regulations for Pressure Relief System*

*6.7.1 General*

*6.7.1.1 All fuel storage tanks shall be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried. Fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 of the Guidelines shall be independent of the pressure relief systems.*

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

*6.7.2 Pressure relief systems for liquefied gas fuel tanks*

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

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

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

*6.7.2.4 The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.*

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

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

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

*.3 PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and*

*.4 sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.*

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

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

*.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.*

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

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

*.1 so constructed that the discharge will be unimpeded and normally be directed vertically upwards at the exit;*

*.2 arranged to minimize the possibility of water or snow entering the vent system; and*

*.3 arranged such that the height of vent exits shall normally not be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways. However, vent mast height could be limited to lower value according to special consideration by the Administration.*

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

*.1 air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and*

*.2 exhaust outlet from machinery installations.*

CR Interpretation of 6.7.2.8

Proposals for alternative pressure relief valve outlet positions will be considered on a case-by-case basis and subject to the submission of an appropriate risk assessment. Such a risk assessment could be based on a ship specific gas dispersion analysis.

*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 above. Means shall be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.*

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

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

*6.7.2.12 All vent piping shall be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.*

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

*6.7.3 Sizing of pressure relieving system*

*6.7.3.1 Sizing of pressure relief valves*

*6.7.3.1.1 PRVs shall have a combined relieving capacity for each liquefied gas fuel tank to discharge the greater of the following, with not more than a 20% rise in liquefied gas fuel tank pressure above the MARVS:*

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

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

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

*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:*

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

where:

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

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

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

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

where:

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

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

$M$ = *molecular mass of the product.*

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

$A$ = *external surface area of the tank ($m^2$), as for different tank types, as shown in Figure 6-6 of the Guidelines.*

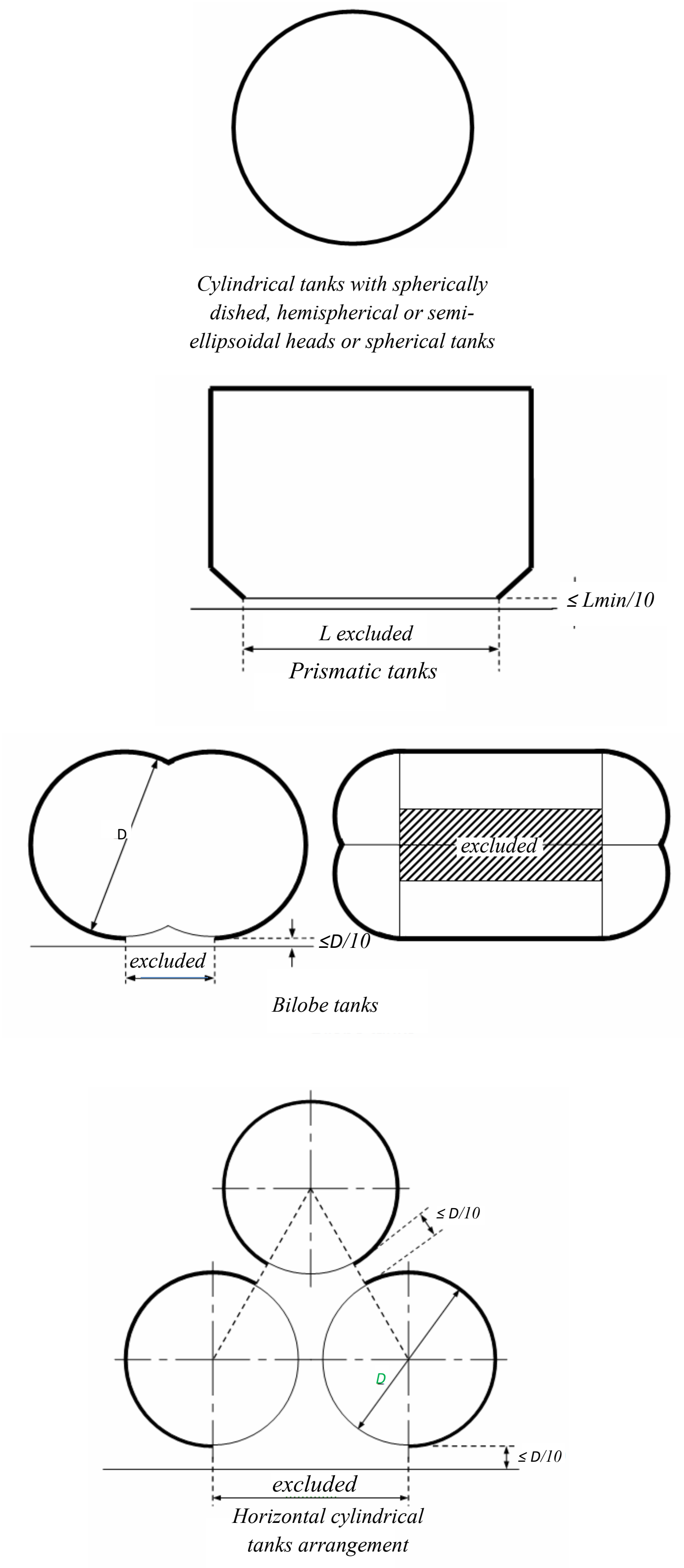

Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks
≤ Lmin/10
L excluded
Prismatic tanks
D
≤D/10
excluded
excluded
Bilobe tanks
≤ D/10
D
≤ D/10
excluded
Horizontal cylindrical tanks arrangement

***Figure 6-6***

IACS Interpretation of 6.7.3.1.1.2 and Figure 6-6
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 – 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

*6.7.3.1.2 For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by coffer dams or surrounded by ship spaces with no fire load the following applies:*
*If the pressure relief valves have to be sized for fire loads the fire factors according may be reduced to the following values:*

$$F = 0.5 \text{ to } F = 0.25$$
$$F = 0.2 \text{ to } F = 0.1$$

*The minimum fire factor is $F = 0.1$*

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

$$M_{air} = Q \times \rho_{air} \text{ (kg/s)}$$

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

*6.7.3.2 Sizing of vent pipe system*

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

*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 above;*

*.2 pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and*

*.3 pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.*

*6.7.3.2.3 Downstream pressure losses*

*.1 Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.*

*.2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, shall not exceed the following values:*

*.1 for unbalanced PRVs: 10% of MARVS;*

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

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

*Alternative values provided by the PRV manufacturer may be accepted.*

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

## *6.8 Regulations on Loading Limit for Liquefied Gas Fuel Tanks*

*6.8.1 Storage tanks for liquefied gas shall not be filled to more than a volume equivalent to 98% full at the reference temperature as defined in 2.2.36 of the Guidelines.*
*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 of the Guidelines, expressed in per cent;*
$FL$ = *filling limit as defined in 2.2.16 of the Guidelines expressed in per cent, here 98%;*
$\rho_R$ = *relative density of fuel at the reference temperature; and*
$\rho_L$ = *relative density of fuel at the loading temperature.*

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

IACS Interpretation of 6.8.2
The alternative loading limit option given under 6.8.2 above is understood to be an alternative to 6.8.1 above and should only be applicable when the calculated loading limit using the formulae in 6.8.1 above, gives a lower value than 95%.

*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%.*

## *6.9 Regulations for The Maintaining of Fuel Storage Condition*

*6.9.1 Control of tank pressure and temperature*

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

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

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

CR Interpretation of 6.9.1.1

6.9.1.1(above) indicates that liquefied gas fuel tanks are to be maintained within their design conditions by one of the listed methods, however one or any combination of the listed methods may be employed provided the aggregate capacity of the means used for BOG management (with the ship in idle condition as specified above) is not less than the normal boil-off rate (NBOR).

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

IACS Interpretation of 6.9.1.1 and 6.9.1.2

Liquefied gas fuel tanks' pressure and temperature should be controlled and maintained within the design range at all times including after activation of the safety system required in 15.2.2 of the Guidelines for a period of minimum 15 days. The activation of the safety system alone is not deemed as an emergency situation.

*6.9.2 Design of systems*

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

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

*6.9.3 Reliquefaction systems*

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

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

*.1 a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;*

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

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

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

6.9.3.3 (CR)

See Annex 2 of the Guidelines for additional requirements in relation to reliquefaction systems.

*6.9.4 Thermal oxidation systems*

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

6.9.4.2 (CR)

See Annex 3 of the Guidelines for additional requirements in relation to gas combustion unit.

*6.9.5 Compatibility*

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

*6.9.6 Availability of systems*

*6.9.6.1 The availability of the system and its supporting auxiliary services shall be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the fuel tank pressure and temperature can be maintained by another service/system.*

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

## *6.10 Regulations on Atmospheric Control within the Fuel Containment System*

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

*6.10.2 The system shall be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.*

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

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

## *6.11 Regulations on Atmosphere Control within Fuel Storage Hold Spaces (Fuel Containment Systems other than Type C Independent Tanks)*

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

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

## *6.12 Regulations on Environmental Control of Spaces Surrounding Type C Independent Tanks*

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

## *6.13 Regulations on Inerting*

CR Interpretation of 6.13

Inerting refers to the process of providing a non-combustible environment by the addition of compatible gases, which may be carried in pressure vessels or produced on board the ship or supplied from an external source.

Where inert gas is also stored for fire-fighting purposes, it is to be carried in separate containers and is not to be used for fuel gas services.

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

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

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

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

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

## *6.14 Regulations on Inert Gas Production and Storage on Board*

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

CR Interpretation of 6.14.1

The system is to be fitted with automatic means to discharge inert gas with an oxygen content exceeding 5% to the atmosphere during start-up and abnormal operation.

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

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

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

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

(CR)
Inert gas piping is not to pass through accommodation spaces, service spaces or control stations.

6.14.5 (CR)
Where an inert gas generator or inert gas storage facilities are installed in the engine room, every effort is to be made to install the equipment as high as possible near to the funnel opening. A low oxygen alarm is to be fitted. In addition, a calculation is to be submitted demonstrating that the oxygen concentration will not be below 15% by volume if the total quantity of inert gas is accidentally released in the space.

However, special consideration may be given on a case by case basis when the inert gas generator is installed in the engine room where it is determined, in consideration with the engine room's ventilation system, that the arrangements are such that under all conditions of operation of the inert gas generator, the oxygen level will be maintained at or above 19%. Such arrangements may include a combination of the following provisions:

.1 Inert gas generator area thoroughly ventilated and/or provisions of direct extraction type ventilation.

.2 The activation of an alarm in case of the engine room mechanical ventilation failure.

.3 Interlock arrangements such that the electrical power supply to the IGS cannot be energized while the ventilation system is not in operation.

# *ANNEX 1 STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF FUEL CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION*

## *1 General*

*1.1 The purpose of this standard is to provide procedures and relevant design parameters of limit state design of fuel containment systems of a novel configuration in accordance with section 6.4.16 of the Guidelines.*

*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 of the Guidelines. 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 6.4.1 through to 6.4.14 of the Guidelines shall be complied with as applicable depending on the fuel containment system concept.*

## *2 Design Format*

*2.1 The design format in this standard is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, $L_d$ , do not exceed design resistances, $R_d$ , for any of the considered failure modes in any scenario:*

$$L_d \leq R_d$$

*A design load is obtained by multiplying the characteristic load by a load factor relevant for the given load category:*

$$F_{dk} = \gamma_{f\times} F_k$$

*where:*

$\gamma_f$ = *is load factor; and*
$F_k$ = *is the characteristic load as specified in 6.4.9 through to 6.4.12 of the Guidelines.*

*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:*

$$L_d = q(F_{d1}, F_{d2}, \ldots\ldots F_{dN})$$

*where q denotes the functional relationship between load and load effect determined by structural analyses.*
*The design resistance* $R_d$ *is determined as follows:*

$$R_d = \frac{R_k}{\gamma_R \times \gamma_C}$$

*Where:*

- $R_k$ *is the characteristic resistance. In case of materials covered by chapter 7 of the Guidelines, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;*
- $\gamma_R$ *is the resistance factor, defined as* $\gamma_R = \gamma_m \times \gamma_s$*;*
- $\gamma_m$ *is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);*
- $\gamma_s$ *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*
- $\gamma_C$ *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 A1-1, 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 A1-1***
***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 5.1 of the Guidelines.*

## 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 A1-2 of the Guidelines shall be used for the assessment of the ultimate limit states.*

**Table A1-2**
**Partial Load Factors**

| Load combination | Permanent loads | Functional loads | Environmental loads |
|---|---|---|---|
| 'a' | 1.1 | 1.1 | 0.7 |
| 'b' | 1.0 | 1.0 | 1.3 |

*The load factors for permanent and functional loads in load combination 'a' are relevant for the normally well-controlled and/or specified loads applicable to fuel containment systems such as vapour pressure, fuel weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.*

*4.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Administration.*

*4.4 In cases where structural failure of the fuel containment system are considered to imply high potential for human injury and significant release of fuel, the consequence class factor shall be taken as $\gamma_C$=1.2. This value may be reduced if it is justified through risk analysis and subject to the approval by the Administration. The risk analysis shall take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended fuel. Conversely, higher values may be fixed by the Administration, for example, for ships carrying more hazardous or higher pressure fuel. The consequence class factor shall in any case not be less than 1.0.*

*4.5 The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the fuel containment systems as described in 6.4.2.1 to 6.4.2.5 of the Guidelines. This may be carried out by calibrating the factors against known successful designs.*

*4.6 The material factor $\gamma_m$ 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 of the Guidelines, the material factor $\gamma_m$ may be taken as:*

*1.1 when the characteristic mechanical properties specified by the Administration typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or*

*1.0 when the characteristic mechanical properties specified by the Administration represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.*

*4.7 The partial resistance factors $\gamma_{si}$ 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 4.8 of the Guidelines of this standard, the partial resistance factors $\gamma_{si}$ shall be taken as follows:*

$$\gamma_{s1} = 0.76 \times \frac{B}{K_1}$$
$$\gamma_{s2} = 0.76 \times \frac{D}{K_2}$$
$$K_1 = Min\left(\frac{R_m}{R_e} \times \frac{B}{A}; 1.0\right)$$
$$K_1 = Min\left(\frac{R_m}{R_e} \times \frac{D}{C}; 1.0\right)$$

*Factors A, B, C and D are defined in 6.4.15.2.3.1 of the Guidelines. $R_m$ and $R_e$ are defined in 6.4.12.1.1.3 of the Guidelines.*

*The partial resistance factors given above are the results of calibration to conventional type B independent tanks.*

*4.8 Design against excessive plastic deformation*

*4.8.1 Stress acceptance criteria given below refer to elastic stress analyses.*

*4.8.2 Parts of fuel containment systems where loads are primarily carried by membrane response in the structure shall satisfy the following limit state criteria:*

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

where:

$\sigma_m$ = *equivalent primary general membrane stress*

$\sigma_L$ = *equivalent primary local membrane stress*

$\sigma_b$ = *equivalent primary bending stress*

$\sigma_g$ = *equivalent secondary stress*

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

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

*Guidance Note:*

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

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + (\tau_{Lxy} + \tau_{bxy})^2}$$

*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:*

$$\sigma_{ms} + \sigma_{bp} \leq 1.25F \text{ (see notes 1, 2 below)}$$
$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F \text{ (see note 2 below)}$$
$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_{g} \leq 3.0F$$

*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:

$\sigma_{ms}$ = *equivalent section membrane stress in primary structure*

$\sigma_{bp}$ = *equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure*

$\sigma_{bs}$ = *section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure*

$\sigma_{bt}$ = *section bending stress in tertiary structure*

$\sigma_{g}$ = *equivalent secondary stress*

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

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

*The stresses $\sigma_{ms}$, $\sigma_{bp}$, $\sigma_{bs}$, and $\sigma_{bt}$ are defined in Annex 1/4.8.4 below.*

*Guidance Note:*

*The stress summation described above shall be carried out by summing up each stress component ($\sigma_x$, $\sigma_y$ and $\tau_{xy}$), and subsequently the equivalent stress shall be calculated based on the resulting stress components.*

*Skin plates shall be designed in accordance with the requirements of the Administration. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.*

*4.8.4 Section stress categories*

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

*Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in Annex 14.8.2 of the Guidelines.*

*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 A1-1.*

*(Stresses $\sigma_{bp}$ and $\sigma_{bs}$ are normal to the cross section shown)*

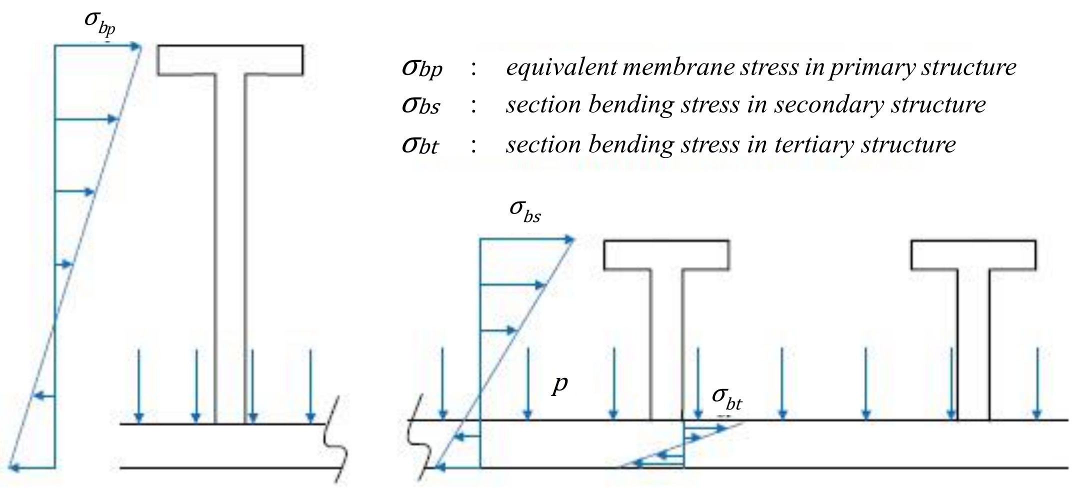



***Figure A1-1***
***Definition of The Three Categories of Section Stress (Stresses $\Sigma_{Bp}$ and $\Sigma_{Bs}$ Are Normal to The Cross Section Shown.)***

*4.9 The same factors $\gamma_C$, $\gamma_m$, $\gamma_{si}$ 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 of the Guidelines 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 of the Guidelines and this Annex.*

*5.2 The load factors for FLS shall be taken as 1.0 for all load categories.*

*5.3 Consequence class factor $\gamma_C$ and resistance factor $\gamma_R$ 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 of the Guidelines. The calculated cumulative fatigue damage ratio for the fuel containment systems shall be less than or equal to the values given in TableA1-3 of the Guidelines.*

***Table A1-3***
***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 of the Guidelines, 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 of the Guidelines. The analysis shall be carried out in accordance with methods laid down in a standard recognized by the Administration.*

## *6 Accident Limit States*

*6.1 Accident design condition as described in 6.4.12.3 of the Guidelines 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 of the Guidelines need not be combined with each other or with environmental loads, as defined in 6.4.9.4 of the Guidelines.*

*6.5 Resistance factor shall in general be taken as 1.0.*

*6.6 Consequence class factors shall in general be taken as defined in Annex 1/4.4 of this standard, but may be relaxed considering the nature of the accident scenario.*

*6.7 The characteristic resistance 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 of the Guidelines, as applicable depending on the fuel containment system concept.*

# ANNEX 2 (CR) RELIQUEFACTION SYSTEMS

## 1 General

1.1 It is understood that reliquefaction systems are likely to be mainly installed on LNG carriers. However for non-LNG carriers there may be instances where reliquefaction systems are utilized as a secondary means of controlling fuel tank pressure so that, as per 6.9.1.1 of the Guidelines, the tank pressure is maintained below the MARVS at all times or that reliquefaction forms a part of the fuel gas supply system process. Accordingly, aspects of the requirements contained within this Chapter may, as applicable, be applied to fuel gas supply systems.

The reliquefaction system typically comprises:

.1 Vapor(BOG)/LNG(condensate) circuit, which is vapor from the fuel tank(s) and LNG return to the fuel tank(s).

.2 Refrigeration circuit for cooling down and re-liquefying the boil-off vapor.

1.2 Capacity

.1 The capacity of the reliquefaction system is to be based on the requirements of 6.9.1.1 of the Guidelines.

.2 The reliquefaction system is to be capable of operating satisfactorily with a reduced rate of boil-off gas.

1.3 LNG Return to Fuel Tanks

.1 The reliquefaction system is to be arranged such that the LNG returned to fuel tanks can be distributed in such a way so as not to cause the liquid level in any fuel tank to exceed that permitted by 6.8.1 of the Guidelines.

.2 Where it is proposed that LNG from the reliquefaction system is returned without the use of a pump, by way of a gravity return or pressure return system, pressure drop calculations for the as-fitted system are to be submitted. The calculations are to consider ship motion and fluid motion inside the fuel tanks.

1.4 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted and are to include, as applicable:

- General arrangement of reliquefaction system compartment, as applicable, including location of the gas detectors, electrical equipment and lighting
- Ventilation systems for reliquefaction system compartment
- Fixed gas detection and alarm systems, and associated shut off and shutdown systems
- Gas fuel piping systems including details of pipes and associated components, design pressures and temperatures
- Gas compressors
- Gas heaters

- Gas storage pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the reliquefaction system compartment
- Electric bonding (earthing) arrangement
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the reliquefaction system (see Annex 2/4.1.2)
- Emergency shutdown arrangements (see Table15-6)
- Operating and maintenance instruction manuals (see Chapter 18 of the Guidelines)
- Forced boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials (submitted for survey verification only).

## 2 Vapor (BOG)/LNG Circuit

2.1 BOG Compressors

.1 The compressors are to be designed in accordance with 9.9 of the Guidelines.

.2 The compressor ESD control are to be designed in accordance with 15.11.4 of the Guidelines.

.3 For pressure and temperature measurement and control, see Table15-6 of the Guidelines.

2.2 LNG Pumps

.1 Material used in the design of the LNG pumps is to be in accordance with 7.4 and 16.1.1 of the Guidelines except that witnessed material testing is not required.

.2 Certification of LNG pumps is to be in accordance with 16.7.4 of the Guidelines.

2.3 Separation of Impurities

Impurities in the boil-off gas, as well as nitrogen, may be separated prior to the return of LNG from the reliquefaction system to the fuel tank(s). The separation of impurities may be through a separator or by other approved means. Details of the separation system are to be submitted.

## 3 Refrigeration System

3.1 General

Refrigeration systems are to be provided with environmentally acceptable refrigerants. The use of ozone depleting refrigerants and those refrigerants contributing to the global warming potential (ODP and GWP), as defined by the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, as amended, is not acceptable.

3.2 Refrigerants

.1 Refrigerants are to be adequate for use in cryogenic shipboard applications in accordance with national or international standards, international treaties adopted by the government(s) and the flag States or other similar legislation laid down by the flag State. Details, such as the chemical properties, toxicity and flammability, together with the supporting data, are to be submitted for review.

.2 There is to be sufficient capacity of refrigerant carried or produced on board to recharge the system at least twice.

.3 Where a cascade system is used requiring onboard storage of refrigerant, the refrigeration system is to be fitted with a receiver capable of holding the complete charge of the refrigerating units. Where each refrigeration unit is fitted with an individual receiver, the capacity is to be sufficient to hold the charge of that unit.

.4 In the case of nitrogen, part of the charge may be discharged/vented to the atmosphere.

3.3 Compressors/Expanders

.1 Air-cooled compressors are to be designed for an air temperature of at least 45℃. Watercooled compressors are to be designed for a water temperature of at least 32℃.

.2 Compressor vibration resulting from gas pressure pulses and inertia forces is to be taken into account in the compressor design and mounting arrangement. Acceptable mounting arrangements include resilient rubber mounts or springs.

.3 Materials used in the manufacture of compressors and expanders are to be in accordance with the Chapters 4 and 5 of the Part XI of the Rules for Steel Ships or 7.4 of the Guidelines, as applicable. Alternatively, materials complying with recognized standards may be considered. Witnessed material testing is not required. The compressor casing design is to be suitable for the maximum design pressure of the high pressure side of the system.

.4 For instrumentation, monitoring and control system for the compressors, see Table15-6.

3.4 Cryogenic Heat Exchangers and Cold Box

.1 The heat exchangers are to be designed, constructed and certified in accordance with 9.10 of the Guidelines. If nitrogen refrigeration compressors are to be located in non-hazardous spaces to mitigate the risks of boil-off gas returning to the refrigeration compressors through the refrigerant system, the pressure in the refrigerant circuit is to be maintained greater than the pressure in the boil-off gas circuit at all times.

.2 Piping inside the cold box is to be of all-welded construction. Where flanged connections are essential, details indicating the necessity for this connection are to be submitted for approval on a case-by-case basis.

.3 For pressure and temperature measurements and controls, see Table 15-6 of the Guidelines.

.4 Where the heat exchanger is enclosed in a cold box, the following requirements apply:

.1 The cold box is to be designed to withstand nitrogen purge pressures likely to be encountered in service and is to be fitted with pressure and vacuum relief devices to prevent over- and under pressurization.

.2 To prevent overpressuring of the cold box by leaking nitrogen or BOG/LNG, a safety relief valve is to be provided. The vent from the cold box safety relief valve is to be led to the weather.

.3 Means of detecting boil-off gas leakage within the cold box is to be provided. Permanently installed gas detectors in accordance with 15.8 of the Guidelines are to be provided. The detection system is to give an audible and visual alarm at the cargo control station and the bridge upon detection of gas leakage.

.4 Where the cold box is insulated, means are to be provided for continuous purging of the insulation spaces with nitrogen or other suitable inert gas.

## 4 Instrumentation and Safety Systems

### 4.1 General

.1 The control system for the reliquefaction system may be connected to an integrated control system or may be a standalone system.

.2 An analysis is to be carried out for the reliquefaction system identifying component criticality.

.3 The overall system design is to be based on single-fault criteria. The system is to be designed such that a single fault of a component will not lead to serious consequences.

### 4.2 Control and Monitoring System

.1 Automatic control, alarm and safety functions are to be provided to prevent operations exceeding preset parameters under specified conditions.

.2 The temperature and pressures in the reliquefaction system are to be controlled as follows:

.1 A control and monitoring system is to be provided in the control room. Additionally, a motor control panel is to be provided in the vicinity of the boil-off gas compressor and the refrigeration compressor motors.

.2 The design of the control system is to be such as to identify faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements 2.2~2.4 of Part VIII of the Rules for Steel Ships, as applicable.

.3 Indications of parameters necessary for the safe and effective operation of the process are to be provided, as per Table 15-6 of the Guidelines.

.4 All electrical control systems are to have two means of power supply and each is to be individually monitored for faults.

.5 All computer-based control systems are to comply with the applicable requirements Chapter 3 of Part VIII of the Rules for Steel Ships.

.6 All electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of Table VIII 2-2 and Table VIII 4-1 of the Rules for Steel Ships.

.3 The gas compressor control and monitoring system is to include anti surge protection.

### 4.3 Safety Shutdown System

An independent shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

.1 Means are to be provided to indicate the parameters causing shutdown.

.2 Upon activation of the safety shutdown system, alarms are to be given at the normal control position and at the local control position.

.3 In the event where shutdown by the safety shutdown system is activated the restart should not occur automatically, until the system has been manually reset.

.4 The safety shutdown system is to be supplied by two sources of power.

.5 Means are to be provided to evacuate LNG remaining in the system after a shutdown.

Safety shutdowns are to be in accordance with Table 15-6 of the Guidelines.

## 5 Electrical System

The electrical systems intended for the reliquefaction system are to be designed, constructed, tested, certified and installed in accordance with the requirements of this Annex and Chapter 14 of the Guidelines, as applicable.

### 5.1 Motor Controllers

Means are to be provided to shut down the compressor from outside the space.

## 6 Location and Installation

Reliquefaction systems and components are to be located in a space which, dependent on installation arrangements, is to meet the requirements for fuel preparation rooms (e.g., location, access, ventilation, gas detection and fire protection) detailed under 5.8, 5.11.2 and 11.3.1 of the Guidelines.

## 7 Oxygen and Toxicity Gas Detection System

The machinery spaces containing the refrigeration equipment are to be fitted with a low oxygen level detection system.

Where the refrigerant being used is considered to be toxic, an alarm system is to be fitted to detect refrigerant concentration exceeding the time-weighted average to which personnel may be repeatedly exposed in the space.

Monitoring and safety system functions are to be provided in accordance with Table 15-6 of the Guidelines.

## 8 Ancillary Systems

Where cooling water is required in refrigeration systems, the cooling water supply is to be as follows:

.1 A minimum of two pumps are to be provided, one of which is to be exclusively provided for this duty.

.2 Where seawater is used, each pump is to have at least two sea suction lines, where practicable leading from sea chests, one port and one starboard.

## 9 Fire Extinguishing Systems

The machinery space containing reliquefaction equipment is to be provided with fire extinguishing arrangements complying with 11.3.1 of the Guidelines.

# ANNEX 3 (CR) GAS COMBUSTION UNITS

## 1 General

1.1 It is understood that Gas Combustion Unit(GCU) plant is likely to be mainly installed on LNG carriers. However, for non-LNG carriers there may be instances where a GCU is utilized as a secondary means of controlling fuel tank pressure so that, as per 6.9.1.1 of the Guidelines, the tank pressure is maintained below the MARVS at all times. Accordingly, as applicable, the GCU is to be available for disposal of boil-off gas that cannot be otherwise utilized during all modes of operations satisfying the requirements of 6.9.1.1 of the Guidelines.

A GCU system will generally contain the following major components:

.1 Boil-off gas compressors

.2 Heaters

.3 Automatic Master Gas Fuel Valve (see 2.2.46 of the Guidelines) and associated pipe work

.4 Pipe work in way of the safe areas where the GCU is located

.5 Gas valve enclosure and venting of the enclosure/hood

.6 Gas burner unit including oil pilot burner and burner management system

.7 Combustion chamber and associated refractory

.8 Forced draft fans, and where fitted, dilution fans

.9 Exhaust trunk from the GCU

1.2 Capacity

.1 The capacity of the GCU system is to be based on the requirements of 6.9.1.1 of the Guidelines.

.2 The GCU unit is to be capable of operating satisfactorily with a reduced rate of boil-off gas.

.3 The GCU is to be designed to function safely during inerting and purging modes of operations if it is intended that the unit consume the gas displaced from the fuel tanks during these operations.

.4 Documentation to show the control system operational capability over the entire range of operations envisaged is to be submitted.

.5 Where the GCU is intended to be used under a free flow mode, design features such as pipe sizing, electrical ignition system and oil pilot burner will be subject to special consideration.

1.3 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted and are to include:

.1 General arrangement of the GCU compartment, including location of the gas detectors, electrical equipment and lighting

.2 Ventilation system for the GCU compartment

.3 Fixed gas detection and alarm systems, and associated shut-off and shutdown systems

.4 Gas fuel piping systems including details of piping and associated components, design pressures and temperatures

.5 Burner management system

.6 Gas compressors

.7 Gas heaters

.8 Gas storage pressure vessels

.9 Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

.10 Details of all electrical equipment in the GCU compartment

.11 Electric bonding (earthing) arrangement

.12 Failure Modes and Effects Analysis (FMEA) (see Annex 3/3.1)

.13 Emergency shutdown arrangements (see Annex 3/10)

.14 Operating and maintenance instruction manuals (see Chapter 18 of the Guidelines)

.15 Forced boil-off gas supply system from the tanks to the consumers

.16 Testing procedures during sea/gas trials (submitted for survey verification only).

## 2 Vapor (BOG) Circuit

2.1 Compressors

Compressors intended to be used for sending the boil-off gas to the GCU may be also used for other duties. The compressors are to be designed in accordance with 9.9 of the Guidelines, except that the compressors are to be capable of being stopped locally and remotely from the control room and from the bridge. For pressure and temperature measurement and control, see Table 15-7 of the Guidelines.

2.2 Heaters

The heaters are to be designed, constructed and certified in accordance with Part V of the Rules for Steel Ships.

2.3 Gas Fuel Supply to the GCU

Gas fuel piping is not to pass through accommodation spaces, service spaces or control stations. Gas fuel piping may pass through or extend into other spaces, provided the arrangements fulfill one of the following:

.1 Gas fuel supply piping is to be installed to comply with 9.6 of the Guidelines.

.2 Alternatively, where the fuel gas supply piping system is a single wall design and the associated valves including the burner gas fuel connection at the GCU are located inside a gas tight compartment inside an engine room or other non-hazardous spaces, the arrangements are to be as follows:

- .1 The pressure in the fuel gas supply line is not to exceed 10 bar.
- .2 The pipes are to be of all-welded construction with flange connections only at connections to equipment.
- .3 This compartment is to have access to the open deck. Where this is not possible, entrance and exits to this compartment from a non-hazardous space are to be through a self-closing gas-tight door.
- .4 The compartment is to be fitted with a mechanical exhaust ventilation system complying with Annex 3/8.
- .5 The compartment is to be fitted with a gas detection system complying with 15.8 and Annex 3/9 of the Guidelines.
- .6 The gas supply pipes are to incorporate a block and bleed valve arrangement and comply with the purging requirements, as referred to in 9.4.4 of the Guidelines.
- .7 The alarms and shutdowns are to comply with Table 15-7 and Annex 3/10, respectively.

## 3 Gas Burner Unit and Burner Management System

3.1 The gas burner management control philosophy for all modes of operation is to be submitted. This should be accompanied by a safety analysis identifying the modes of failures and shutdown and startup sequences of the system.

3.2 Where free flow of BOG to the GCU is intended, the GCU control system is to be designed to safely manage such mode of operation.

3.3 Gas nozzles should be fitted in such a way that gas fuel is ignited by the flame of the oil pilot burner described in Annex 3/4 below or by an electrical ignition system.

3.4 The gas burner is to be fitted with a flame scanner. The flame scanner is to have dual scanners or a scanner of the self-checking type. The flame scanner control should provide for a trial by ignition period of not more than 10 seconds, during which time gas fuel may be supplied to establish a flame. If the flame is not established within 10 seconds, the gas fuel supply to the burner is to be immediately shut off automatically. In the case of flame failure, shut-off is to be achieved within 4 seconds following flame extinguishment. In the case of failure of the flame scanner, the gas fuel is to be shut off automatically.

3.5 After flame extinguishment, the gas burner supply piping and combustion chamber is to undergo the purge sequences required by 10.4.8 and 10.4.10 of the Guidelines.

3.6 The burner management system is to be arranged such that the gas burner cannot be ignited until forced draft and dilution air fan flow is established.

3.7 The gas burner unit is to have the capability of automatic operation with manual local controls. A manually operated shut-off valve is to be fitted on the pipe of each gas burner.

## 4 Oil Pilot Burner/Electrical Ignition System

Each gas fuel burner unit is to be fitted with an oil pilot burner and/or electrical igniter. The arrangements of the piping system, storage and heating of the fuel for the oil pilot burner are to be in accordance with the applicable requirements 4.4 of Part VI of the Rules for Steel Ships.

The oil pilot burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. The shut-off is to be achieved within 6 seconds following flame extinguishment. In the case of failure of the flame scanner, the fuel to the oil pilot burner is to be shut off automatically.

## 5 Forced Draft Fans and Dilution Fans

There is to be a minimum of 2 forced draft fans for each GCU. Each fan is to be sized such that the total capacity is not less than 100% of the total capacity required to support the full rated capacity of the GCU with one fan kept in reserve. Forced draft fan motors are to be located in a non-hazardous space. Where operational or structural requirements are such as to make it impossible to install the motors in the non-hazardous space, the following certified safe type motors are to be provided:

- Increased safety type with flameproof enclosure; or

- Pressurized type.

There is to be a minimum of 2 dilution fans provided. Each dilution fan is to be sized such that the total capacity is not less than 100% of the total capacity required to support the full rated capacity of the GCU with one dilution fan kept in reserve. Means are to be provided for measuring and monitoring of air flow in the forced draft and the dilution air flow streams on the discharge side.

## 6 Combustion Chamber and Associated Refractory

6.1 The combustion chamber walls are to be protected with insulated fire bricks/refractory and/or a cooling system. Hot surfaces likely to come in contact with the crew during operation are to be suitably guarded or insulated.

6.2 The combustion chamber and the refractory are to be designed so that in the event of failure of the dilution fans, the temperature of the casing, or the outer casing where double casing is fitted, does not exceed 230°C.

6.3 Where the casing of the combustion chambers is required to be cooled due to temperature limitation of the material used, this may be achieved by dilution fans, as per Annex 3/5. Alternative means of cooling will be considered subject to approval of the details.

6.4 The design is to take into consideration the expected frequency of operation of the GCU and possible vibrations.

6.5 The design of the combustion chamber is to be such that the flame length always remains within the extent of the GCU under all modes of operation.

6.6 The combustion chamber is to be of suitable form such as not to present pockets where gas may accumulate.

## 7 Exhaust Gas Piping

7.1 Exhaust gas temperature at the discharge from the GCU is not to exceed 535°C during any operating mode.

7.2 The requirements of 4.8 of Part VI of the Rules for Steel Ships for exhaust gas piping of internal combustion engines apply.

## 8 Ventilation

Ventilation arrangements are to comply with Chapter 13 of the Guidelines, except that where the gas fuel supply pipe is a single wall design, as described in Annex 3/2.3.2, the ventilation of the spaces containing the GCU is to be in accordance with the following requirements:

8.1 The GCU compartment is to be fitted with a mechanical ventilation system having a capacity of at least 30 air changes per hour based on the gross volume of the compartment. The ventilation system is to be provided with at least two fans. Each fan is to be sized such that the total capacity is not less than 100% of the total capacity required with one fan kept in reserve.

8.2 Ventilation ducting is to be situated in the GCU compartment in such a manner as to provide immediate evacuation of the leaked gas from the entire compartment without the possibility of pockets of gas remaining in isolated corners. Either a gas dispersion analysis or a physical smoke test under all possible operating modes is to be conducted in order to prove that the inlets in the ducting are strategically positioned for the effective removal of the leaked gas from the compartment.

8.3 The ventilation system in the GCU compartment is to be separate from those intended for other spaces. The ventilation inlet and discharge are to be respectively from and to a non-hazardous area.

8.4 The ventilation fans are to be of non-sparking construction (see 13.3.3 of the Guidelines) and electric motors for these fans are to be located outside of the airflow stream.

## 9 Gas Detection

Gas detection arrangements are to comply with 15.8, except that where the gas fuel supply pipe is a single wall design as described in Annex 3/2.3.2, the gas detection arrangements are to be in accordance with the following requirements:

- There are to be at least two independent fixed gas detection systems in accordance with 15.8 of the Guidelines, fitted in the GCU compartment for continuous monitoring of the presence of leaked gas.

When the GCU is fitted with a double casing, care is to be exercised to preclude the possibility of gases leaking into and being trapped in pockets of the outer casing. Gas detection probes within the casing and explosion-relief doors on the outer casing are to be provided.

Monitoring and safety system functions are to be provided in accordance with Table 15-7 of the Guidelines.

## 10 Automatic Shutdown System

The monitoring and safety system functions for the GCU gas fuel supply systems are to be provided in accordance with Table 15-7 of the Guidelines. The alarms are to be provided at the GCU control station. In addition, a summary alarm is to be provided at the navigation bridge. Shutdown arrangements are to comply with 9.4 of the Guidelines, except that where the gas fuel supply pipe is a single wall design as described in Annex 3/2.3.2 of the Guidelines, the shutdown arrangements are to be as follows:

10.1 In the event of leakage of gas in the compartment, an alarm is to be given when the gas concentration within the compartment reaches 30% of LEL by volume.

10.2 If the gas concentration in the compartment continues to rise to 60% of LEL by volume, the master gas fuel valve is to close automatically, the block and bleed valves are to operate and all non-certified electrical equipment within the compartment is to be isolated from their electrical supply. The ventilation fans are to continue operating until the gas concentration in the compartment has reached a safe level for entry.

10.3 In the event of ventilation system failure in the compartment (see Annex 3/8 of the Guidelines), an alarm is to be given in the control center and on the bridge, the entire GCU is to shut down and the gas shut-off valve is to close automatically.

## 11 Fire Extinguishing System

The compartment described in Annex 3/2.3.2 is to be provided with a fixed fire extinguishing system complying with 8.4.1 of Part IX of the Rules for Steel Ships.

# *CHAPTER 7 MATERIAL AND GENERAL PIPE DESIGN*

## *7.1 Goal*

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

## *7.2 Functional Requirements*

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

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

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

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

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

## *7.3 Regulations for General Pipe Design*

*7.3.1 General*

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

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

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

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

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

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

*7.3.2 Wall thickness*

*7.3.2.1 The minimum wall thickness shall be calculated as follows:*

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

*where:*

$t_0$ = *theoretical thickness*

$t_0$ = $PD / (2.0Ke + P)$ (mm)

*with:*

$P$ = *design pressure (MPa) referred to in 7.3.3 of the Guidelines;*

$D$ = *outside diameter (mm);*

$K$ = *allowable stress (N/mm²) referred to in 7.3.4 of the Guidelines; 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:*

$b = Dt_0 / 2.5r$ (mm)

*with:*

$r$ = *mean radius of the bend (mm);*

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

$a$ = *negative manufacturing tolerance for thickness (%).*

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

*7.3.3 Design condition*

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

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

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

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

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

*.5 the relief valve setting on a pipeline system.*

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

7.3.3.3 (CR) pressure surge protection

Where there is a risk of a pressure surge in a pipeline caused by an instantaneous closure of the gas shut-off valve or shutdown of gas consumer (e.g., in the pipe downstream of the compressor), the piping system is to be designed to withstand a surge of gas pressure.

*7.3.4 Allowable stress*

*7.3.4.1 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 7.3.2.1 of the Guidelines 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/mm²); and*

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

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

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

*Note 14:*

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

*Note 15:*

*For ships on voyages of restricted duration, P0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank. Reference is made to the Application of amendments to gas carrier codes concerning type C tank loading limits (SIGTTO/IACS).*

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

*.1 stresses due to the weight of the piping system;*

*.2 acceleration loads when significant; and*

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

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

*7.3.5 Flexibility of piping*

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

7.3.5.2 (CR)

The arrangement and installation of high pressure fuel piping is to provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the main engine, without running the risk of fatigue problems. The length and configuration of the branch lines are important factors in this regard.

*7.3.6 Piping fabrication and joining details*

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

(CR)

Design calculations, materials, dimensions and gasket data are to be submitted for non-standard flanges.

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

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

(CR)

Joints on the entire length of high pressure gas fuel supply lines are to be butt-welded joints with full penetration and are to be fully radiographed, except where specially approved.

Pipe joints other than welded joints at the specially approved locations identified above are to comply with recognized standards or may be accepted subject to specific approval on a case-bycase basis.

For all butt-welded joints of high pressure gas fuel supply lines, post-weld heat treatment is to be performed dependent on the type of material.

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

*7.3.6.4.1 Direct connections*

*.1 Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than –10℃, 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 –10℃ 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 –55℃.*

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

*7.3.6.4.2 Flanged connections*

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

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

*.1 For design temperatures colder than –55℃, only welded neck flanges shall be used; and*

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

*7.3.6.4.3 Expansion joints*

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

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

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

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

*7.3.6.4.4 Other connections*

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

## *7.4 Regulations for Materials*

### *7.4.1 Metallic materials*

CR Interpretation of 7.4.1

Materials in general are to comply with the requirements of Part XI and Part XII of the Rules for Steel Ships.

Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with cryogenic liquids or gases are to be in compliance with this Chapter.

For CNG tanks, the use of alternative materials not covered by this Chapter may be accepted provided such materials are approved in connection with the design and that they are verified or tested by the Surveyor, as applicable, as complying with the approved specifications.

*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℃.*

*Table 7-2: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0℃ and down to –55℃.*

*Table 7-3: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below –55℃ and down to –165℃.*

*Table 7-4: Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to –165℃.*

*Table 7-5: Plates and sections for hull structures required by 6.4.13.1.1.2 of the Guidelines.*

## *Table 7-1*

***PLATES, PIPES (SEAMLESS AND WELDED) (1),(2), SECTIONS AND FORGINGS FOR FUEL TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0°C***

| | | |
|---|---|---|
| ***CHEMICAL COMPOSITION AND HEAT TREATMENT*** | | |
| ◆ *Carbon-manganese steel* | | |
| ◆ *Fully killed fine grain steel* | | |
| ◆ *Small additions of alloying elements by agreement with the Administration* | | |
| ◆ *Composition limits to be approved by the Administration* | | |
| ◆ *Normalized, or quenched and tempered (4)* | | |
| ***TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS*** | | |
| ***Sampling frequency*** | | |
| ◆ *Plates* | | *Each "piece" to be tested* |
| ◆ *Sections and forgings* | | *Each "batch" to be tested.* |
| ***Mechanical properties*** | | |
| ◆ *Tensile properties* | | *Specified minimum yield stress not to exceed 410 N/mm$^2$ (5)* |
| ***Toughness (Charpy V-notch test)*** | | |
| ◆ *Plates* | | *Transverse test pieces. Minimum average energy value (KV) 27J* |
| ◆ *Sections and forgings* | | *Longitudinal test pieces. Minimum average energy value (KV) 41J* |
| ◆ *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 procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.*

*(5) Materials with specified minimum yield stress exceeding 410 N/mm$^2$ may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.*

***Table 7-2***

***PLATES, SECTIONS AND FORGINGS (1) FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0℃ AND DOWN TO –55℃***

***MAXIMUM THICKNESS 25 MM (2)***

| | | | | | |
|---|---|---|---|---|---|
| ***CHEMICAL COMPOSITION AND HEAT TREATMENT*** | | | | | |
| ◆ *Carbon-manganese steel* | | | | | |
| ◆ *Fully killed, aluminium treated fine grain steel* | | | | | |
| ◆ *Chemical composition (ladle analysis)* | | | | | |
| | *C* | *Mn* | *Si* | *S* | *P* |
| | *0.16% max.(3)* | *0.70-1.60%* | *0.10-0.50%* | *0.025% max.* | *0.025% max.* |
| | *Optional additions: Alloys and grain refining elements may be generally in accordance with the following* | | | | |
| | *Ni* | *Cr* | *Mo* | *Cu* | *Nb* |
| | *0.80% max.* | *0.25% max.* | *0.08% max.* | *0.35% max.* | *0.05% max.* |
| | *V* | | | | |
| | *0.10% max.* | | | | |
| | *Al content total 0.020% min. (Acid soluble 0.015% min.)* | | | | |
| ◆ *Normalized, or quenched and tempered (4)* | | | | | |
| ***TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS*** | | | | | |
| ***Sampling frequency*** | | | | | |
| ◆ *Plates* | | | *Each 'piece' to be tested* | | |
| ◆ *Sections and forgings* | | | *Each 'batch' to be tested* | | |
| ***Mechanical properties*** | | | | | |
| ◆ *Tensile properties* | | | *Specified minimum yield stress not to exceed 410 N/mm$^2$ (5)* | | |
| ***Toughness (Charpy V-notch test)*** | | | | | |
| ◆ *Plates* | | | *Transverse test pieces. Minimum average energy value (KV) 27J* | | |
| ◆ *Sections and forgings* | | | *Longitudinal test pieces. Minimum average energy (KV) 41J* | | |
| ◆ *Test temperature* | | | *5℃ below the design temperature or -20℃ whichever is lower* | | |

*Notes:*

*(1) The Charpy V-notch and chemistry regulations for forgings may be specially considered by the Administration.*

*(2) For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:*

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

*The impact energy value shall be in accordance with the table for the applicable type of test specimen. Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5℃ below design temperature or -20℃ 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℃*

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

*(5) Materials with specified minimum yield stress exceeding 410 N/mm$^2$ may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.*

*Guidance:*

*For materials exceeding 25 mm in thickness for which the test temperature is -60℃ or lower, the application of specially treated steels or steels in accordance with Table 7-3 of the Guidelines may be necessary.*

**Table 7-2**
**(CR) Requirements for Design Temperatures Below 0℃ and Down to -55℃**

| | | | |
|---|---|---|---|
| **Tension Test** | | | |
| Tensile Strength | 400 – 490 N/mm$^2$ | 440 – 590 N/mm$^2$ | 490 – 620 N/mm$^2$ |
| Yield Strength Min. | 235 N/mm$^2$ | 315 N/mm$^2$ | 355 N/mm$^2$ |
| **Elongation (%)** in | | | |
| 200 mm or<br>50 mm or<br>$5.6\sqrt{A}$ | 21<br>24<br>22 | 20<br>23<br>21 | 19<br>22<br>20 |
| A = Cross Sectional area of Specimen in mm$^2$ | | | |
| Impact Test (Charpy V-notch) | | | |
| Frequency: Plates – See Table 7-2 – each 15 tons of each heat | | | |
| Heat Treatment: See Table 7-2 and Note 1 for Table 7-2 | | | |

Notes:

(1) Control Rolled (for sections only) or Thermo-Mechanical Controlled Process may also be considered as an alternative to normalizing or quenching and tempering.

***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 –165°C [2]***

***Maximum thickness 25 mm [3],[4]***

| *Minimum design temp. (°C)* | *Chemical composition[5] and heat treatment* | *Impact test temp. (°C)* |
|---|---|---|
| *-60* | *1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [6]* | *-65* |
| *-65* | *2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6],[7]* | *-70* |
| *-90* | *3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6],[7]* | *-95* |
| *-105* | *5% nickel steel – normalized or normalized and tempered or quenched and tempered[6],[7] and [8]* | *-110* |
| *-165* | *9% nickel steel – double normalized and tempered or quenched and tempered [6]* | *-196* |
| *-165* | *Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated [9]* | *-196* |
| *-165* | *Aluminum alloys; such as type 5083 annealed* | *Not required* |
| *-165* | *Austenitic Fe-Ni alloy (36% nickel) Heat treatment as agreed* | *Not required* |

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

*Notes:*

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

*(2) The regulations for design temperatures below –165°C shall be specially agreed with the Administration.*

*(3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:*

| *Material thickness (mm)* | *Test temperature (°C)* |
|---|---|
| *$25 < t \leq 30$* | *10°C below design temperature* |
| *$30 < t \leq 35$* | *15°C below design temperature* |
| *$35 < t \leq 40$* | *20°C below design temperature* |

*The energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.*

*(4) For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.*

*(5) The chemical composition limits shall be in accordance with recognized standards.*

*(6) Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by the Administration.*

*(7) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Administration.*

*(8) A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.*

*(9) The impact test may be omitted subject to agreement with the Administration.*

## *Table 7-4*

***Pipes (Seamless and Welded)(1), Forgings(2) and Castings(2) for Fuel and Process Piping for Design Temperatures below 0°C and down to –165°C (3)***

***Maximum thickness 25 mm***

| *Minimum design temp.(℃)* | *Chemical composition(5) and heat treatment* | *Impact test* | |
|---|---|---|---|
| | | *Test temp. (℃)* | *Minimum average energy (J)* |
| -55 | *Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed.(6)* | (4) | 27 |
| -65 | *2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered.(6)* | -70 | 34 |
| -90 | *3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.(6)* | -95 | 34 |
| -165 | *9% nickel steel(7). Double normalized and tempered or quenched and tempered.* | -196 | 41 |
| | *Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated.(8)* | -196 | 41 |
| | *Aluminum alloys; such as type 5083 annealed* | | *Not required* |
| ***TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS*** | | | |
| ***Sampling frequency*** | | | |
| ◆ *Each 'batch' to be tested.* | | | |
| ***Toughness (Charpy V-notch test)*** | | | |
| ◆ *Impact test: Longitudinal test pieces* | | | |

*Notes:*

*(1) The use of longitudinally or spirally welded pipes shall be specially approved by the Administration.*

*(2) The regulations for forgings and castings may be subject to special consideration by the Administration.*

*(3) The regulations for design temperatures below -165℃ shall be specially agreed with the Administration.*

*(4) The test temperature shall be 5℃ below the design temperature or -20℃ whichever is lower.*

*(5) The composition limits shall be in accordance with Recognized Standards.*

*(6) A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.*

*(7) This chemical composition is not suitable for castings.*

*(8) Impact tests may be omitted subject to agreement with the Administration.*

***Table 7-5***

***Plates and Sections for Hull Structures Required by 6.4.13.1.1.2 of The Guidelines.***

| ***Minimum design temperature of hull structure (°C)*** | ***Maximum thickness (mm) for steel grades*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ***A*** | ***B*** | ***D*** | ***E*** | ***AH*** | ***DH*** | ***EH*** | ***FH*** |
| *0 and above* | *Recognized Standards* | | | | | | | |
| *down to -5* | *15* | *25* | *30* | *50* | *25* | *45* | *50* | *50* |
| *down to -10* | *x* | *20* | *25* | *50* | *20* | *40* | *50* | *50* |
| *down to -20* | *x* | *x* | *20* | *50* | *x* | *30* | *50* | *50* |
| *down to -30* | *x* | *x* | *x* | *40* | *x* | *20* | *40* | *50* |
| *Below -30* | *In accordance with Table 7-2, except that the thickness limitation given in Table 7-2 and in footnote 2 of that table does not apply.* | | | | | | | |

*Note:*
*'x' means steel grade not to be used.*

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

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

*7.4.1.4 Where required the outer pipe or duct containing high pressure gas in the inner pipe shall as a minimum fulfil the material regulations for pipe materials with design temperature down to –55℃ in Table 7-4.*

*7.4.1.5 The outer pipe or duct around liquefied gas fuel pipes shall as a minimum fulfil the material regulations for pipe materials with design temperature down to –165℃ in Table 7-4.*

# *CHAPTER 8 BUNKERING*

## *8.1 Goal*

*8.1.1 The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.*

(CR) Plans and data to be submitted

.1 General arrangement of the gas fuel bunkering system including location of the gas detectors, electrical equipment and lighting

.2 Detailed drawings of the bunkering station, manifolds, valves, couplings and control stations

.3 Gas fuel piping systems including details of piping and associated components, design pressures, temperatures and insulation where applicable

.4 Material specifications for manifolds, valves and associated components

.5 Weld procedures, stress relieving and non-destructive testing plans

.6 Ventilation system

.7 Fixed gas detection and alarm systems, and associated shut-off and shutdown systems

.8 Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

.9 Details of all electrical equipment in the bunkering and control stations

.10 Equipotential bonding and insulating flange arrangement

.11 Emergency shutdown (ESD) arrangements and ESD flow chart

.12 Operating and maintenance instruction manuals

.13 Testing procedures during sea/gas trials (submitted for survey verification only)

## *8.2 Functional Requirements*

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

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

(CR)

The purpose of this Chapter is to define the on-board requirements for fuel bunkering systems to enable safe and effective transfer of LNG or CNG from the bunker supplier (ship/truck/terminal) to the ship gas storage system.

It is understood that the on-board bunkering system would typically comprise a bunkering station located on either side of the ship. Each station would have provision for one bunkering line and one return line together with inert gas purging facility, associated relief/safety valves and control station. The LNG or CNG is led by piping from the bunker station to the gas storage tank(s). Consideration is to be given to relevant aspects of related standards such as ISO 28460, EN 1473, EN 1474, etc., and the ISO Technical Specification ISO/TS 18683 'Guidelines for systems and installations for supply of LNG as fuel to ships'.

## *8.3 Regulations for Bunkering Station*

### *8.3.1 General*

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

IACS Interpretation of 8.3.1.1

The special consideration is to 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 closed-circuit television(CCTV)

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

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

(CR)

Drip trays as per 5.10 of the Guidelines are to be provided beneath bunkering connections to protect the hull structure from low temperatures. Where the leakage containment arrangements are such that damage to the hull structure from accidental spillage of LNG during bunkering operations cannot be precluded, additional measures such as a low-pressure water curtain, are to be fitted under the bunkering station to provide for additional protection of the hull steel and the ship's side structure.

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

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

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

*8.3.2 Ships' fuel hoses*

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

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

## *8.4 Regulations for Manifold*

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

8.4.2 (CR)
Arrangements are to be provided for the installation of an emergency release system. These are to be designed to prevent damage and spark generation and to minimize release of LNG when activated. The release system is to incorporate suitable means to prevent accidental operation and is to be of the fail release type. It is recognized that these features may well be within the scope of the bunker supplier (bunkering ship, truck or shore side facility).

8.4.3 (CR)
Filters/strainers are to be fitted to prevent the transfer of foreign objects.

## *8.5 Regulations for Bunkering System*

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

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

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

(CR)
The remote operated valve is to be of the fail closed type (closed on loss of actuating power), be capable of local manual closure and have positive indication of the actual valve position.

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

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

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

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

(CR)
An ESD system in accordance with 15.5.4 of the Guidelines is to be operational during bunker operations to enable a safe shut down in the event of an emergency during bunker delivery.

*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 of the Guidelines from the trigger of the alarm to full closure of the remote operated valve required by 8.5.3 of the Guidelines shall be adjusted.*

## 8.6 (CR) Gas Detection

Enclosed or semi-enclosed bunker stations and ducts around fuel gas bunker pipes are to be fitted with permanently installed gas detectors in accordance with 15.8 of the Guidelines.

Monitoring and safety system functions are to be provided in accordance with Table 15-3 of the Guidelines.

# *ANNEX 4 LNG-BUNKER DELIVERY NOTE**

***LNG AS FUEL FOR***

***SHIP NAME :________________________ IMO NO. :_________***

***Date of delivery:***

## *1. LNG-Properties*

| | | |
|---|---|---|
| *Methane number *** | -- | |
| *Lower calorific (heating) value* | *MJ/kg* | |
| *Higher calorific (heating) value* | *MJ/kg* | |
| *Wobbe Indices Ws / Wi* | *MJ/m³* | |
| *Density* | *kg/m³* | |
| *Pressure* | *MPa (abs)* | |
| *LNG temperature delivered* | *℃* | |
| *LNG temperature in storage tank(s)* | *℃* | |
| *Pressure in storage tank(s)* | *MPa (abs)* | |

## *2. LNG-Composition*

| | | |
|---|---|---|
| *Methane, $CH_4$* | *% (kg/kg)* | |
| *Ethane, $C_2H_6$* | *% (kg/kg)* | |
| *Propane, $C_3H_8$* | *% (kg/kg)* | |
| *Isobutane, $iC_4H_{10}$* | *% (kg/kg)* | |
| *N-Butane, $nC_4H_{10}$* | *% (kg/kg)* | |
| *Pentane, $C_5H_{12}$* | *% (kg/kg)* | |
| *Hexane; $C_6H_{14}$* | *% (kg/kg)* | |
| *Heptane; $C_7H_{16}$* | *% (kg/kg)* | |
| *Nitrogen, $N_2$* | *% (kg/kg)* | |
| *Sulphur, S* | *% (kg/kg)* | |
| *negligible<5ppm hydrogen sulphide, hydrogen, ammonia, chlorine, fluorine, water* | | |

***3. Net Total delivered: ______________t, ____________________MJ ______________m³***

***Net Liquid delivery:______________GJ***

***4. Signature(s):***

*Supplier Company Name, contact details:_________________________*

*Signature:____________________Place/Port ___________ date:___________________*

*Receiver:______________________________*

* *The LNG properties and composition allow the operator to act in accordance with the known properties of the gas and any operational limitations linked to that.*

** *Preferably above 70 and referring to the used methane number calculation method in DIN EN 16726. This does not necessarily reflect the methane number that goes into the engine.*

# CHAPTER 9 FUEL SUPPLY TO CONSUMERS

## 9.1 Goal

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

(CR) Plans and data to be submitted

.1 General arrangement of the fuel preparation room including location of the gas detectors, electrical equipment and lighting

.2 Doors and other openings in fuel preparation rooms

.3 Ventilation ducts of fuel preparation rooms

.4 Material specifications for compressors, pumps, evaporators, vaporizers, condensers, coolers, heaters, valves and associated components

.5 Ventilation systems for the fuel preparation room

.6 Fixed gas detection and alarm systems, and associated shut-off and shutdown systems

.7 Gas fuel piping systems including details of piping and associated components, design pressures, temperatures and insulation where applicable

.8 Weld procedures, stress relieving and non-destructive testing plans

.9 Gas compressors

.10 Vaporizers/Heaters

.11 Pressure vessels

.12 Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

.13 Details of all electrical equipment in the fuel gas supply room

.14 Electric bonding (earthing) arrangement

.15 Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the fuel gas supply system

.16 Emergency shutdown arrangements

.17 Operating and maintenance instruction manuals

.18 Forced and natural boil-off gas supply system from the tanks to the consumers

.19 Testing procedures during sea/gas trials (submitted for survey verification only).

## *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 of the Guidelines. In particular the following apply:*

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

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

*.3 fuel lines outside the machinery spaces shall be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.*

(CR)
The requirements specified in this Chapter are intended to cover the fuel supply arrangements and systems installed on board to deliver natural gas from the fuel tank to the prime movers and gas consumers. Installed arrangements and systems will vary from ship type to ship type and from prime mover to prime mover and hence may for example include compressors, process skids or cryogenic fuel preparation equipment, etc. Dependent on the specific arrangements reference may also need to be made to the requirements for reliquefaction components and systems given under 6.9.3 of the Guidelines.

## *9.3 Regulations on Redundancy of Fuel Supply*

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

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

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

9.3.4 (CR)
The propulsion and auxiliary arrangements and fuel supply systems are to be arranged so that in the case of emergency shutdown of the fuel gas supply the propulsion and maneuvering capability, together with power for essential services, can be maintained. Under such a condition, the remaining power is to be sufficient to provide for a speed of at least 7 knots or half of the design speed, whichever is the lesser.

Dual fuel engine installations are considered to meet this redundancy objective by their inherent provision of independent gas and liquid fuel systems.

## *9.4 Regulations on Safety Functions of Gas Supply System*

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

(CR)

Tank valves are to be remotely operated, be of the fail closed type (closed on loss of actuating power) are to be capable of local manual closure and have positive indication of the actual valve position.

*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 of the Guidelines.*

CR Interpretation of 9.4.2

If the master gas fuel valve is located in an enclosed space such as a gas valve unit room, that space is to be protected against gas leakage by another automatic shutdown valve arranged for closure in the event that gas leakage is detected within the enclosed space or loss of ventilation for the duct or casing or loss of pressurization of the double wall gas fuel piping occurs.

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

*9.4.4 Each gas consumer shall be provided with "double block and bleed" valves arrangement. These valves shall be arranged as outlined in .1 or .2 so that when the safety system required in 15.2.2 of the Guidelines 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 2 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 1 of the shutoff valves in series and the bleed valve can be incorporated into 1 valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.*

*9.4.5 The 2 valves shall be of the fail-to-close type, while the ventilation valve shall be fail-to-open.*

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

*Note 16:*

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

*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.*

(CR)
An automatic purge is to be activated upon automatic closure of the master gas fuel valve. Arrangements are to be such that the piping between the master gas fuel valve and the gas consumer will be automatically purged with inert gas.

*9.4.8 There shall be 1 manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.*

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

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

9.4.11 (CR)
Provision is to be made for inerting and gas-freeing the gas fuel piping system. Discharges are to be led to a safe location in the open air.

9.4.12 (CR)
The transient response characteristics of the fuel gas supply and control systems are to be such that transient variations in fuel gas demand would not cause unintended shutdown of the fuel gas supply system.

9.4.13 (CR)
Where high pressure relief valve discharges may create noise levels exceeding those permitted for occasional exposure without ear protection by the Code on Noise Levels on Board Ships, means shall be provided to reduce such noise levels within acceptable limits.

9.4.14 (CR)
Where the auxiliary heat exchange circuits are likely to contain gas in abnormal conditions as a result of a component failure (refer to FMEA), they are to be arranged with gas detection in the header tank. Alarm is to be given when the presence of gas is detected. Vent pipes are to be independent and to be led to a non-hazardous area and are to be fitted with a flame screen or flame arrester.

*Note 17:*
*The shutdown shall be time delayed to prevent shutdown due to transient load variations.*

(CR) Acceptable means of rapid detection are:
.1 An orifice or flow fuse detecting excess flow and located close to the point of entry to the machinery space;

.2 A combined excess flow detector with automatic shut off valve located as close as possible to the point of entry to the machinery space;

.3 A low pressure detector located close to the engine inlet connection.

9.4.15 (CR)

Engines are to be stopped when the gas concentration detected by the engine machinery space gas detectors specified by 15.8.1.3 of the Guidelines reaches 60% LEL.

## *9.5 Regulations for Fuel Distribution Outside of Machinery Space*

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

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

(CR)

Gas vent piping from tank relief valves, bunker station relief valves and block and bleed valves may be single walled when located on the open deck.

*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*

*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 in 15.8 shall be provided. Other solutions providing an equivalent safety level may also be accepted by the Administration.*

*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.*

*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.*

## *9.6 Regulations for Fuel Supply to Consumers in Gas-Safe Machinery Spaces*

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

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

CR Interpretation of 9.6.1.2

The ventilation is always to be in operation when there is fuel in the fuel gas supply piping. The applicable master gas fuel valve is to automatically close if the required air flow is not established and maintained by the ventilation system.

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

*9.6.2 The connecting of gas piping and ducting to the gas injection valves shall be completely covered by the ducting. The arrangement shall facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.*(18)

## 9.7 Regulations for Gas Fuel Supply to Consumers in ESD-Protected Machinery Spaces

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

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

## 9.8 Regulations for The Design of Ventilated Duct, Outer Pipe against Inner Pipe Gas Leakage

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

*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*

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

$k$ = *1.31 for $CH_4$*

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

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

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

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

## *9.9 Regulations for Compressors and Pumps*

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

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

*.1 environmental;*

*.2 shipboard vibrations and accelerations;*

*.3 effects of pitch, heave and roll motions, etc.; and*

*.4 gas composition.*

*9.9.3 Arrangements shall be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.*

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

9.9.5 (CR)

Gas compressors for pressurizing boil-off or vaporized gas are to be designed and tested in accordance with Annex 5/7.5 of the Guidelines.

*Note 18:*

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

## 9.10 (CR) Vaporizers, Heaters and Pressure Vessels

9.10.1 Heat exchangers used for heating or vaporizing fuel gas and pressure vessels used to store or treat fuel gas supply liquids or vapors are to be designed, constructed and certified in accordance with 6.4.15.3 of the Guidelines, as applicable. For the requirements for reliquefaction cryogenic heat exchangers, see Annex 2/2.4.

9.10.2 For pressure and temperature measurements and controls, see Table 15-5 of the Guidelines.

9.10.3 Arrangements are to be provided to prevent in-operation freezing of the intermediate heat exchange mediums containing products with higher freezing points than LNG, such as Ethylene Glycol, by establishing adequate flow prior to establishing flow of LNG to the heat exchanger/vaporizer or by some other equivalent control strategy.

9.10.4 Where the auxiliary heat exchange circuits are likely to contain gas in abnormal conditions as a result of a component failure (refer to FMEA), they are to be arranged with gas detection in the header tank. Alarm is to be given when the presence of gas is detected. Vent pipes are to be independent and to be led to a non-hazardous area and are to be fitted with a flame screen or flame arrester.

## 9.11 (CR) LNG Pumps

9.11.1 LNG pumps used in fuel gas supply systems are to be entirely independent of all other pumps.

9.11.2 Material used in the design of the LNG pumps is to be in accordance with 7.4 and 16.1.1 of the Guidelines, except that witnessed material testing is not required.

9.11.3 Certification of LNG pumps is to be in accordance with 16.7.3 of the Guidelines.

## 9.12 (CR) Ancillary Systems

Where cooling/heating mediums are required in fuel gas supply or ancillary systems, the supply is to be arranged as follows:

9.12.1 A minimum of two pumps are to be provided, one of which is to be exclusively provided for this duty.

9.12.2 Where seawater is used, each pump is to have at least two sea suction lines, where practicable leading from sea chests, one port and one starboard.

# CHAPTER 10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS

## 10.1 Goal

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

(CR) Plans and data to be submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted and are to include:

.1 General arrangement of engine compartment(s), including location of the gas detectors, electrical equipment and lighting

.2 Ventilation system

.3 Fixed gas detection and alarm systems, and associated shut-off and shutdown systems

.4 Gas fuel piping system including details of pipes and associated components, design pressures and temperatures

.5 Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

.6 Details of the electrical equipment

.7 Electric bonding (earthing) arrangement

.8 Arrangement and details of crankcase protection

.9 Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the engines for each engine type

.10 Arrangement of explosion protection for air inlet manifolds and for exhaust manifolds including design basis and size calculations

.11 Emergency shutdown arrangements

.12 Operating and maintenance instruction manuals

.13 Testing procedures during sea/gas trials (submitted for survey verification only).

.14 Engine specific time referenced by 10.3.1.7 of the Guidelines, after which if the engine has not started then the fuel gas supply is to be shut off and exhaust system is to be purged.

## *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 of the Guidelines. 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*

CR Interpretation of 10.2.3

Explosion venting as referenced by 10.2.3 above is to be led to a non-hazardous area in the open air, or to an alternative acceptable location to safely dispose of the gas, through a flame arrester.

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

(CR)

The requirements specified in this Chapter are additional to all other relevant requirements of the Rules for Steel Ships.

## *10.3 Regulations for Internal Combustion Engines of Piston Type*

### *10.3.1 General*

*10.3.1.1 The exhaust system shall be equipped with explosion relief ventilation sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned gas in the system.*

*10.3.1.1.1 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.*

.1 (CR)
Interpretation - Engine Exhaust System Explosion Relief.
Explosion relief valves or other appropriate protection against explosion, such as burst discs of an approved type, are to be provided on the exhaust manifolds and exhaust system.
Alternatively, documentation showing that the system has sufficient strength to withstand a worst-case explosion may be submitted for consideration.
Protective devices that require dismantling or replacement prior to continued engine operation are not to be installed on single engine main propulsion exhaust system installations.
The arrangement and location of the protective devices is to minimize the dangers to personnel and equipment from operation of the protective device, with discharge being directed to a safe location through a flame screen or flame arrester.

.2 (CR)
Interpretation - Engine Exhaust System Purging.A manual purging connection is to be provided.

In the event that an Otto cycle engine stops during the gas fuel mode of operation, the exhaust system is to be purged for a sufficient time, to discharge the gas that may be present. The purge time is to be based on a minimum of four air changes of the volume of the exhaust system. See also 10.3.1.7 below for additional requirements regarding exhaust system purging.

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

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

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

CR Interpretation of Auxiliary System Venting

Auxiliary system circuits, such as cooling water or dry/wet sump lubricating oil systems, that are likely to contain gas in normal conditions or abnormal conditions as a result of a component failure (refer to FMEA) are to be arranged in accordance with the following requirements:

.1 Auxiliary system circuits are to be arranged to avoid cross connection between engine systems and to avoid the migration of gas to non-hazardous areas;

.2 Vent pipes are to be independent and to be led to a safe location external to the machinery space and to be fitted with a flame screen or flame arrester.

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

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

*10.3.1.7 For engines starting on fuels covered by the IGF 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.*

CR Interpretation of 10.3.1.7

The “engine specific time” referenced by 10.3.1.7 above is to be specified by the engine manufacturer.

10.3.1.8 (CR)

Gas fueled engines are to be capable of operating with possible variations of the Methane Number and Heat Value and the extent of those permitted variations are to be declared by the manufacturer and detailed in the operation and maintenance manuals required by 18.2 of the Guidelines.

10.3.1.9 (CR)

The engine transient response characteristics are to be appropriate for the intended application. Engines driving generators are to meet the transient response requirements 3.2 of Part VII of the Rules for Steel Ships, however, consideration may be given to the use of alternative performance criteria such as ISO 8528 where appropriately matched with the ship power management system.

10.3.1.10 (CR)

For type tests and shop tests using gas as fuel, a sample of the fuel gas is to be taken and analyzed and the results retained for record.

10.3.1.11 (CR) Engine Combustion Air Intakes

Where engine combustion air intakes are located inside the engine compartment, these are to be situated as far apart as practicable from the gas fuel supply pipe such that, in the event of a gas leak, the risk of the gas entering the intake is minimized.

Engine combustion air intakes located outside the engine compartment are to be lead from a non-hazardous area at least 1.5 m away from the boundaries of any hazardous area.

Engine combustion air intakes are to be located at least 10 m from LNG tank pressure relief outlets.

Proposals for combustion air intakes located closer than 10 m from LNG tank pressure relief outlets will be considered on a case-by-case basis and subject to submission of an appropriate risk assessment. Such a risk assessment could be based on a ship specific gas dispersion analysis. In such cases engine air intakes on deck between 4.5m and 10 m from any LNG tank relief valve outlet are to be provided with automatic air intake shut-off valves or equivalent devices, which are to take the signal for activation from the engine over speed detection system. Furthermore the air intake is to be provided with a gas detection system which will activate audible and visual alarms when the gas concentration reaches 20% of LEL.

In no case are combustion air intakes to be located less than 4.5 m from a LNG tank relief valve outlet.

10.3.1.12 (CR) Air Inlet Manifolds

An explosion relief valve or other appropriate protection against explosion is to be provided on the air inlet manifolds.

Protective devices that require dismantling or replacement prior to continued engine operation are not to be installed on single engine main propulsion installations.

The arrangement and location of the protection devices is to be such as to minimize the dangers to personnel and equipment from operation of the protective device.

Alternatively, documentation may be submitted for consideration showing that the system has sufficient strength to withstand a worst-case explosion, or that the assumed possible gas explosion in the air inlet manifold is not a plausible scenario due to the inherent design characteristics.

10.3.1.13 (CR) Protection of Crankcase

.1 Explosion Relief Valves.

The explosion relief valves are to be in accordance with 3.4.3 of Part IV of the Rules for Steel Ships. High pressure gas fueled engines are to be fitted with explosion relief valves in way of each crank throw.

.2 Ventilation.

To avoid the possible spread of fire between engines following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

The crankcase is to be continuously vented and arrangements are to be made so that any blow-by gas may readily reach the vent. However fresh air ventilation of the crankcase, and any arrangement which could produce a flow of external air within the crankcase, is not permitted.

Crankcase ventilation pipes are to be as small as practicable, in accordance with manufacturer's recommendations, to minimize the inrush of air after a crankcase explosion. If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase is not to exceed $2.5 \times 10^{-4}$ N/mm$^2$.

The outlet of the vent line is to be led to a non-hazardous area in the open air, or to an alternative acceptable location to safely dispose of the gas, through a flame arrester.

.3 Inerting.

For trunk piston engines operating according to the Otto cycle, a means is to be provided for inerting and aerating the crankcase before opening the crankcase doors for maintenance.

The crankcase is to be fitted with a gas sampling connection in order to allow the measurement of the gas concentration by portable gas detection equipment.

.4 Instrumentation.

Instrumentation installed inside the crankcase is to be of the certified safe type. The crankcase is to be protected by an oil mist detector approved in accordance with 3.4.5 of Part IV of the Rules for Steel Ships.

.5 Warning Notice.

For trunk piston engines operating according to the Otto cycle, the warning notice required by 3.4.7 of Part IV of the Rules for Steel Ships is to include a caution that the crankcase is not to be opened until adequate precautions have been taken to determine that no gas remains trapped in the crankcase.

10.3.1.14 (CR) Protection Against Explosion

A Failure Modes and Effects Analysis (FMEA) is to be carried out by the engine manufacturer in order to determine necessary additional safeguards to address the hazards associated with the use of gas as a fuel.

The analysis is to identify all plausible scenarios of gas leakage and the resulting possible explosion. Then the analysis is to identify necessary means to control the identified explosion hazards.

The FMEA is to be submitted to the Society for review.

10.3.1.15 (CR) Gas Valve Unit (GVU)/Gas Valve Train (GVT) Room/Enclosure

Where the GVU/GVT is located in a dedicated compartment or space, the safety principles and arrangements of that compartment are to be the same as those required for an ESD-Protected machinery space detailed in 13.5.2 through 13.5.4, 12.3.3 and 5.11.4 of the Guidelines.

In those instances where the GVU/GVT components are intended to be encased in a gas tight box or enclosure of minimum volume, for the purpose of being located in a non-hazardous space, the safety principles and arrangements of that enclosure are to be the same as those required for an ESD-protected machinery space detailed in 13.5.2 through 13.5.4, and 12.3.3 of the Guidelines. Such GVU/GVT enclosures are to be designed to a recognized standard acceptable to the Society for the design pressure as per 9.8.2 or 13.8.4 of the Guidelines, as applicable. The hydrostatic test pressure of the GVU/GVT enclosure is to be not less than the design pressure of the fuel gas for low pressure systems. For high pressure fuel gas systems, the hydrostatic test pressure of the GVU/GVT enclosure is to be not less than the design pressure of the duct as per 9.8.2 of the Guidelines.

### *10.3.2 Regulations for dual fuel engines*

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

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

CR Interpretation of 10.3.2.2

Changeover to and from gas fuel operation is only to be possible at a power level and under conditions where it can be done with acceptable reliability and safety.

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

10.3.2.4 (CR) Testing

Type testing and shop testing are to be as specified in 3.12 of Part IV of the Rules for Steel Ships. Dual fuel engines are to be so tested for both fuel modes. Tests performed are to demonstrate smooth changeover from gas to oil mode and from oil to gas mode at the test load points. The rapid (emergency) changeover testing is only required from gas to oil mode. The engine manufacturer is to specify the lowest permissible operating speeds for both oil and gas modes, and these speeds are to be demonstrated during the type tests.

*10.3.3 Regulations for gas-only engines*

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

*10.3.4 Regulations for multi-fuel engines*

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

*10.3.4.2 An automatic system shall be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine shall automatically change to an alternative fuel mode. Manual activation shall always be possible.*

| | ***GAS ONLY*** | | ***DUAL FUEL*** | ***MULTI FUEL*** |
|---|---|---|---|---|
| ***IGNITION MEDIUM*** | *Spark* | *Pilot fuel* | *Pilot fuel* | *N/A* |
| ***MAIN FUEL*** | *Gas* | *Gas* | *Gas and/ or Oil fuel* | *Gas and/ or Liquid* |

10.3.5 (CR) "Pre-Mixed" Gas Fuel Engines

.1 For gas fueled engine types where the gas is introduced into the combustion air flow before it enters the cylinder or cylinder head port (so called "pre-mixed system"), the engine components containing the gas/air mixture, such as inlet manifold, turbo-charger, charge air cooler, etc., are to be considered as parts of the fuel gas supply system.

Such engine types are to be installed in a machinery space complying with the requirements for ESD-protected machinery spaces detailed under 5.6 of the Guidelines. Alternative arrangements may be considered on a case-by-case basis.

.2 In addition to the requirements for engine component pressure tests given under Table IV 3-4 of Part IV of the Rules for Steel Ships, engine components containing gas/air mixtures during normal operation such as inlet manifolds, charge air coolers, charge air cooler casings, turbocharger compressor casings, etc., are to be pressure tested at 1.5 times the maximum working pressure of the component. These tests are to be carried out by the manufacturer whose certificate of test will be acceptable.

.3 Flame arresters are to be installed before each cylinder head, unless otherwise justified, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

## *10.4 Regulations for Main and Auxiliary Boilers*

*10.4.1 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.*

*10.4.2 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.*

*10.4.3 Burners shall be designed to maintain stable combustion under all firing conditions.*

(CR) Boiler Burners:

.1 Firing Condition

The burners are to maintain complete and stable combustion under all operating conditions including the minimum rate of firing, or during any sudden change in gas firing rate between maximum and minimum rates.

.2 Valve Marking

Important valves are to be plainly marked to indicate the service controlled. Detailed operating instructions are to be posted, including a sequence of valve operations, where this information is necessary for effective emergency action.

*10.4.4 On main/propulsion boilers an automatic system shall be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.*

*10.4.5 Gas nozzles and the burner control system shall be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Administration to light on gas fuel.*

*10.4.6 There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.*

*10.4.7 On the fuel pipe of each gas burner a manually operated shutoff valve shall be fitted.*

*10.4.8 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.*

*10.4.9 The automatic fuel changeover system required by 10.4.4 above shall be monitored with alarms to ensure continuous availability.*

*10.4.10 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.*

*10.4.11 Arrangements shall be made to enable the boilers purging sequence to be manually activated.*

10.4.12 (CR) Boiler Casings

When the boilers are fitted with a double casing, care is to be exercised to preclude the possibility of gases leaking into and being trapped in pockets of the inner casing. Gas-detection probes within the casing and explosion-relief panels on the outer casing are to be provided.

## *10.5 Regulations for Gas Turbines*

*10.5.1 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a safe location, away from personnel.*

*10.5.2 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 5.6 and 9.7 of the Guidelines, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.*

*10.5.3 Gas detection systems and shutdown functions shall be as outlined for ESD protected machinery spaces.*

*10.5.4 Ventilation for the enclosure shall be as outlined in chapter 13 of the Guidelines for ESD protected machinery spaces, but shall in addition be arranged with full redundancy (2 x 100% capacity fans from different electrical circuits).*

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

*10.5.6 Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply shall be shutdown.*

*10.5.7 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.*

10.5.8 (CR)

See Annex 5 for additional requirements in relation to dual fuel gas turbines.

# ANNEX 5 (CR) DUAL FUEL GAS TURBINE PROPULSION SYSTEM

## 1 General

1.1 Application

The requirements in this Annex are applicable to natural gas and liquid fuel propulsion gas turbine and piping systems based on the following concepts:

.1 The dual fuel gas turbine is fitted in a gas-tight enclosure to minimize the risk associated with gas leakage, fire and any other hazards associated with the use of gas and oil fuel.

.2 The entire gas turbine enclosure is to encase the gas turbine(s) and, as a minimum, the associated equipment necessary for starting and continuous operation. Even though the internal space of the enclosure will contain the high pressure gas supply line, integrity is achieved by the required ventilation system, gas detection systems and associated safety shutdown systems, as well as the fire protection and firefighting systems which are equivalent to a localized protected space, as per Chapter II-2 of SOLAS 1974 as amended.

.3 Dual fuel gas turbines intended for use as prime movers for propulsion (mechanical drive or generator drive), electric power generation and auxiliary services equipment are to be designed, constructed, tested, certified and installed in accordance with the requirements of this Annex, in addition to the Rules for Steel Ships.

.4 Piping systems serving gas turbine engines, such as fuel oil, gas fuel, lubricating oil, starting air/hydraulic and exhaust gas systems, are to be in compliance with Part VI of the Rules for Steel Ships, Chapters 7 and 9 of the Guidelines.

.5 Gas turbine(s) used for propulsion are to be designed to enable maneuvering from stop to full ahead and vice-versa without a delay using either gas or liquid fuel. When changeover of fuel is activated during all modes of operation, this should be smooth, without interruptions to the power, as far as practicable.

.6 Both liquid fuel and boil-off gas may be used simultaneously.

.7 Gas turbines are to be capable of operation with a range of gas composition mixtures reflective of that likely to be encountered during service.

## 2 Arrangement of Dual Fuel Gas Turbines

2.1 General

The dual fuel gas turbine power plant arrangement may consist of the dual fuel gas turbine as the prime mover driving rotating equipment, such as generator(s), a gearbox, couplings and propulsion shafting, together with associated equipment that may include; a starter, governor and fuel control, enclosure, piping, and auxiliary systems and exhaust gas/waste heat recovery boilers and instrumentation, monitoring and control systems.

2.1.1 Where the dual fuel gas turbine prime mover and the minimum associated equipment necessary for its operation are fitted in an enclosure, this enclosure is to be of minimum size, as far as practicable without compromising the accessibility, maintainability and operability. This enclosure is to be provided with effective ventilation and gas detection systems.

## 3 Plans and Data to be Submitted

3.1 In addition to the plans and particulars required as per 2.2 of the Part IV of the Rules for Steel Ships, the following plans and particulars for dual fuel applications are also to be submitted:

.1 General arrangements showing location of the power plant and individual items of machinery, such as the gas turbine units(s), exhaust gas boilers, turbo generators(s), diesel generators and other associated equipment (such as the GCU, reliquefaction plant and the gas supply line to the consumers)

.2 General arrangement of the gas turbine engine enclosure, including location of the gas detectors, electrical equipment, lighting and ventilation, etc.

.3 Gas fuel manifold arrangement and details, including design pressure and temperatures, operational schematics, material specifications and bill of materials

.4 Enclosure, including size and dimensions, gas tightness, entrance and exits and other openings, such as ventilation intakes and outlets

.5 Ventilation systems details, including inlet cooling air calculations for the enclosure

.6 Fixed gas detection and alarm systems, and associated shut off and shutdown systems

.7 Gas fuel piping systems, including details of pipes and associated components, design pressures and temperatures, operational schematics, flange/joints loadings, material specifications and bill of materials

.8 Gas compressors, with details such as type, size, mechanical components, materials used and details of alarms, indication, shutdown and control system.

.9 Mist separators

.10 Vaporizers

.11 Heat exchangers, including BOG heaters, BOG coolers, etc.

.12 Pressure vessels, including recovery tanks, etc.

.13 Descriptions and schematic diagrams for control and monitoring systems, including set points for abnormal conditions together with control logic for the entire power plant and individual items in the systems.

.14 Details of the electrical equipment in the turbine engine enclosure

.15 Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the dual fuel gas turbine

.16 Electric bonding (earthing) arrangement

.17 Emergency shutdown arrangements

.18 Operating and maintenance instruction manuals

.19 Schematic diagram showing gas and fuel supply lines from the source to the consumers for the entire power plant system

.20 Forced boil-off and LNG vaporization gas supply system from the tanks to the consumers

.21 Testing procedures during sea/gas trials (submitted for survey verification only).

## 4 Materials of Construction

4.1.1 Materials entering into the construction of gas turbine engine propulsion systems are to comply with the 2.3 of the Part IV of the Rules for Steel Ships and the requirements of the 7.4 of the Guidelines.

4.2 Materials subjected to low temperatures are to comply with the requirements of Chapters 4 and 5 of Part XI of the Rules for Steel Ships.

## 5 Dual Fuel Propulsion Gas Turbines

5.1 General

.1 Gas turbines as components are to comply with the requirements of 10.2.4 and 10.5 of the Guidelines and Chapter 2 of Part IV of the Rules for Steel Ships.

.2 The dual fuel gas turbine is to be fitted within an acoustic gas-tight enclosure providing effective gas detection, fire protection, ventilation and cooling, as per the requirements given in this Annex. Alternatively, the gas turbines may be located in a space containing other machinery, provided that the installation arrangements of the gas turbine are in compliance with 9.6 of the Guidelines.

.3 The design of the gas fuel manifold and nozzles is to provide complete venting upon shutdown to prevent gas leakage and fire, unless the manufacturer demonstrates to the satisfaction of CR by experience with similar installations or test data that the gas manifold evacuation is not necessary.

.4 The design of the gas turbine is also to provide positive means of evacuating all unburned gas from the combustor, turbine and exhaust collector.

.5 Gas turbine fuel oil piping system is to comply with the requirements of Chapter 4 of Part VI of the Rules for Steel Ships except that gas fuel piping within the enclosure need not be jacketed or shielded.

5.2 Gas Fuel Manifold

.1 The gas fuel manifold fitted on the engine is to be designed for the maximum design pressure, temperatures, thermal growth, dominant resonances and vibrations that may be experienced after installation.

.2 The installation arrangements of the gas fuel manifold, piping and pipe fittings, joints, etc., are to provide the necessary flexibility to accommodate the oscillating movements of the engine without risk of fatigue failure in the piping connections to the engine.

.3 The gas fuel manifold and piping configuration is to be approved and certified by CR as per the engine manufacturer's design.

.4 All metallic gas fuel manifold/lines are to be of corrosion resistant steel.

.5 All mechanical joints are to be of welded type, as far as practicable, and designed to prevent accidental leakage onto hot engine parts and any other source of ignition. Shielding or other means are to be provided to prevent this.

.6 Non-welded connections will be subject to special consideration.

5.3 Gas Fuel Control Valves

.1 Actuation is to be from the machinery control room, both at local and remote locations. Where the source of power to the actuator is electrical, the electrical source should be from the emergency power supply or provided with a backup power supply. All shut-off valves are to close rapidly and completely. All shut-off valves are to be of fail-safe type.

.2 All internal elements of the gas fuel system are to be resistant to corrosion.

## 6 Gas Turbine Enclosure

6.1 General

.1 The gas turbine is to be resiliently or rigidly mounted to a structural foundation within an acoustically and thermally insulated enclosure.

.2 The enclosure design is to maintain all components within their safe working temperature under expected operating conditions to minimize the risk of fire from sources of ignition such as hot spots. This is to prevent damage by heat to the adjacent components by providing effective fire prevention, ventilation and cooling.

6.2 Construction

.1 Unless the fuel gas piping up to the gas turbine inlet is of double wall design and in full compliance with 9.6 of the Guidelines, the enclosure is to be gas-tight.

.2 The enclosure is to be of steel construction and designed for removal of major components, such as the generator, reduction gear (where fitted) or gas turbine. The manufacturer is to identify maintenance access envelopes for removal of the above major components.

.3 The enclosure is to maintain structural integrity with the access panels removed.

.4 The enclosure is to be arranged such that if the removal of the access panels and doors while the turbine may be operating causes an unsafe condition, then the access panels and doors are to be provided with interlocks or other means to automatically secure the turbine prior to removal of the access panel.

.5 The enclosure, including enclosure cooling ducting, is to be designed as airtight, as required by Annex 5/6.2.1, and capable of withstanding the pulsation pressure that emanates from the gas turbine during operation.

.6 The enclosure is to be sized to allow for maximum deflection of the mounted equipment without the equipment striking the enclosure.

.7 Where one enclosure serves two gas turbines, an internal wall is to be provided.

.8 Where a gas turbine is located inside a gas-tight acoustic enclosure, the internal space of the enclosure is considered to be a Category A machinery space, hence, the separation of this space from the adjoining spaces and fire protection of this space is to be in accordance with the applicable requirements in the Rules for Steel Ships and SOLAS 1974, as amended.

.9 Each enclosure is to form a gas-tight seal at all piping, ducting and electrical connections that penetrate the enclosure walls.

.10 A suitable means of inspection such as a glass inspection window or a CCTV system is to be installed in the enclosure such that it is possible for operators to observe the engine and its major components, including gearbox accessories, intake, piping and instrumentation, during operation looking for evidence of fluid leakage, fire, smoke or other abnormal operating conditions without entering the enclosure.

.11 The inspection windows may be installed in the enclosure access doors where the door location meets the internal viewing requirements. Where the enclosure is considered a category A machinery space, the windows are to be of the same fire rating as the bulkhead in which they are installed.

.12 Interior lighting is to be provided in the enclosure to allow a clear view of all components from the inspection windows. Enclosure access doors are to be provided in locations that will allow maintenance personnel easy access to both sides of all major components within the enclosure.

Access to the air intake of the engine is to be provided.

.13 The enclosure is to be sound and thermally insulated.

.14 Thermal and acoustic insulating material is to be provided with protection to minimize the possibility of absorption of oils, grease and moisture.

.15 Protective metal guards are to be provided to avoid wear or puncture of exposed insulated areas subject to mechanical abrasion.

.16 A temperature sensor is to be placed inside and adjacent to each gas turbine engine compartment entry to indicate compartment internal temperature.

.17 A placard stating necessary safety precautions to be taken by personnel is to be provided at the engine space access if entrance to the engine compartment is required after gas turbine engine shutdown.

.18 A hazard label is to be placed on or adjacent to each access to the enclosure and internal to the enclosure, located so as to be visible upon entry, and is to provide appropriate personnel warnings.

.19 Each base and enclosure is to be provided with floor drains to prevent the accumulation of fluids.

The floor drains are to be situated to negate any effect of base and enclosure installation rake on drainage. Fluid drains are to be arranged so as to prevent migration of fluids to the gas turbine exhaust area and hot section.

.20 Means are to be provided for drainage of the enclosure space in a safe manner. Where an enclosure is fitted with a water-based fire protection system, a fixed permanently installed bilge system for the enclosure is to be provided.

## 6.3 Enclosure Air Intakes and Exhaust System

### 6.3.1 General

.1 The design and arrangement of the system is to minimize pressure drop and back pressure, turbulence, noise and ingestion of water or spray.

.2 The systems are to be designed and supported to prevent stress loading of the flexible connections and expansion joints.

.3 The design is to also minimize the transfer of vibration to the supporting structure and withstand stresses induced by weight, thermal expansion, engine vibration, working of the ship and pressure thrust caused by the exhaust gas and intake air.

.4 The perforated plate interior surface of the exhaust ducts is to be held in place using retainer clips welded to the duct structure.

.5 All systems are to be designed to withstand dynamic forces encountered by motion of the ship at sea, as specified in Table IV 1-1 of Part VI of the Rules for Steel Ships.

.6 All sections of systems exposed to the weather are to be self-supporting without any wire, rope, etc.

.7 Air intake and exhaust ducting is to be of welded construction as far as practicable and is to be in accordance with the requirements of the Rules for Steel Ships for 5.7 and 5.8 of the Part XII.

.8 Cover plates for maintenance and access openings are to be bolted on and are to have handles or other means to facilitate their removal. All cover plates are to open outwards.

.9 Flexible metal hoses or expansion joints of an approved type are to be used at the engine air intakes, as well as at the exhaust outlets and elsewhere, as required for flexibility. The flexible joints are to be provided with internal flow liners. The method of connecting these flexible metal hoses or expansion joints to the gas turbines is to be in accordance with builders' and manufacturers' recommendations.

.10 Adjustments for misalignment through the use of expansion joints are not permitted.

.11 Provisions are to be made to allow for differences in expansion between the stack and the uptakes.

.12 Uptakes are to be fitted with expansion joints to allow for thermal expansion and to prevent overstressing of the uptake plating and ship structure.

.13 The systems, including air filters, moisture separators, intake silencers, exhaust mufflers, water traps and valves, are not to impose a pressure drop or back pressure which will exceed the acceptable values as specified in the engine specifications.

.14 The internal surface of ducting is to be as smooth as practicable. Strengthening members are to be on the external surface of the duct.

.15 Where ducts are large enough to permit entry of personnel for inspection and maintenance access, they are to be provided with removable cover plates and grab rods or access hatch.

.16 Gas passages are to be free of internal obstruction, except that grab rods and ladder rungs are to be installed for inspection and maintenance.

.17 Ducts too small to permit entry of personnel are to be provided with openings and removable cover plates at the ends of horizontally installed sections for cleanout.

.18 The systems are to be provided with drains at the low points. Collected drainage is to be led overboard, if environmentally safe and possible, or connected to a drain system.

.19 The intakes, cooling air and exhaust duct openings are to be located above the waterline and positioned to minimize the probability of raw water entering the air inlet, cooling air and exhaust systems. These are also to be located to minimize the probability of sea spray being entrained in the air flow and carried into air inlets and cooling ducts.

.20 Air intake, cooling air and exhaust ducts are to be positioned and designed to minimize the probability that exhaust gases from any engine or any other source are drawn into the air inlet or cooling air duct of gas turbine.

.21 The exhaust gases outlet from the gas turbine are to be clear of any ventilation system inlets.

6.3.2 Combustion Air Intake System

.1 General

.1 The air intake system is to consist of all devices from the weather to the front face of the gas turbine, and is to be in accordance with the requirements of this Annex. Air intakes are not to be located in hazardous areas.

.2 The engine manufacturer is to provide the following performance requirements for compressor inlet airflow:

- Inlet pressure loss (max.), in mm of $H_2O$
- Air compressor inlet flow distortion (max.), in percent. Alternatively, manufacturer is to approve the design of the aerodynamics of intake.
- Air compressor pre-swirl angle (max.), in degrees
- Air compressor counter-swirl angle (max.), in degrees
- Total pressure fluctuation (max.), in mm of $H_2O$
- Turbulence (max.) in percent, where turbulence is defined as the root mean square of the fluctuating pressure level between 0.5 and 700 Hz as measured by a fast response pressure transducer divided by the steady state (average) total pressure

.3 Each unit of installed equipment requiring combustion air is to have a separately ducted air system from the weather directly to the gas turbine.

.4 Combustion air shall be ducted from the weather, through a separator system, directly to each propulsion gas turbine.

.5 The design is to be such that the pressure drop in the gas turbine combustion air intake does not exceed that specified by the engine manufacturer.

.6 Gas turbine intake systems are to be designed to withstand compressor surging, as specified by the gas turbine manufacturer.

.7 Ducting material for the gas turbine combustion air intake systems is to be corrosion resistant alloys or stainless steel.

.8 Fasteners inside duct assemblies exposed to the weather are to be corrosion resistant and to be of material that will prevent a galvanic reaction with the surrounding material.

.9 A moisture separator, as described below, is to be installed, unless another effective arrangement is approved. The moisture separator elements are to have separation efficiency, as required by the gas turbine engine manufacturers. The elements are to be readily accessible for inspection and easily removed manually for cleaning or replacement.

.10 Each gas turbine engine intake is to consist of louvers or vanes, moisture separator water wash manifold (if applicable to the moisture separator type).
The following items are also to be provided:

- Moisture separator panels, differential pressure safety system to activate alarms and open blow-in doors, intake support structure, drainage and discharge ducting.
- The piping, wiring and fittings associated with the above are to be provided.

.11 Moisture separator filters are to be provided and are to be accessible for inspection and removal.

.12 The moisture separator is to have the capability of being cleaned, both manually or by the moisture separator waterwash system.

.13 Filter materials are to be fire resistant and of a consistent material density throughout. Removable moisture separator filters are to be enclosed in a rigid, self-contained frame fabricated of corrosion resistant alloys or stainless steel.

.14 The moisture separator filter assemblies are to meet or exceed the salt efficiency requirements as specified by the gas turbine manufacturer.

.15 A fresh water connection for cleaning the separator filter is to be provided to reduce the pressure drop across the filter.

.16 Differential pressure indicators for each intake system are to be provided.

.17 The intake system is to withstand compressor surging, as specified by the engine manufacturer.

.18 Splitters and turning vanes are to be provided as necessary to meet the engine manufacturer’s performance requirements for compressor inlet flow as specified.

.19 Fasteners on the internal side of the intake system, such as nuts and bolts, are to be secured with some type of locking device, such as lock wire or self-locking nuts, so as not to become adrift.

.20 The intake system is to be fitted with protective foreign object damage (FOD) screens to prevent entrance of foreign objects. The screens are not to impede or limit the blow-in panels from operating.

.2 Anti-icing Systems

.1 When the intake system is to include an anti-icing system that allows the gas turbine to operate during cold weather conditions, the gas turbine manufacturer’s requirements governing airflow temperature distortion, distribution and rate of change is to be complied with in the design of the system that introduces thermal energy into the intake.

.2 The cold weather protection system for the intake and its filtration system is to provide sufficient thermal energy to prevent ice and snow accumulation from occurring across the face of, and within, any weather opening protected by devices such as louvers or the intake’s filtration system, so as to preclude pressure drop growth.

.3 In addition, any filter drain troughs or drainage related mechanisms are to be heated so that these devices continue to function as intended during cold weather operations.

.4 Temperature and humidity sensors and ice detection sensors are to be provided for anti-icing control and to indicate an alarm condition in the machinery control system.

These sensors are to be installed near the weather entry to the gas turbine intakes, to indicate the condition of the air entering. In addition, a temperature and humidity sensor is to be located near the intake bellmouth to the gas turbine.
The temperature and humidity sensors are to indicate icing conditions whenever ambient temperature is below 5°C and the relative humidity is above 70%. The temperature and humidity sensors are to be capable of providing continuous temperature and humidity readings.

6.3.3 Exhaust System

.1 General

.1 Each gas turbine unit is to have a separate exhaust system which ducts the gases to the weather directly or through a waste heat recovery boiler.

.2 The exhaust gas outlets are to be located where the exhaust gases will not contaminate ventilation or combustion air intakes, interfere with the ship’s crew, impinge on ship equipment, or create a fire or explosion hazard. These are to be designed to discharge gases clear of the ship to the maximum extent practicable.

.3 Exhaust systems are not to run through accommodations or other spaces where such may affect habitability. Where it is necessary to run the exhaust system through these spaces, adequate insulation is to be provided and flanged joints are not to be installed in such spaces. The piping and ducting are to be of all-welded construction.

.2 Gas Turbine Exhaust System

.1 Gas turbine exhaust systems are to comply with the requirements of Chapter 4 of Part VI of the Rules for Steel Ships.

.2 Gas turbine uptakes are to be designed to function as self-supporting pipes.

.3 The exhaust systems are to include the expansion joints and thermal and acoustic insulation, as required, unless arranged to prevent return of gas to other engines.

.4 The exhaust system from gas turbine engines is not to be directly connected to the exhaust systems of other engines.

.5 Where the exhaust of a gas turbine is connected with another oil- or gas- fired unit, such as a duct-fired/waste heat recovery boiler or similar device, means are to be provided to prevent the back flow of combustible gases to the gas turbine. The arrangement is to be provided with a positive means of closure to isolate the gas turbine when not in use.

.6 Ducting material for the gas turbine and auxiliary equipment exhaust systems, which is exposed to the internal gas flow, is to be fabricated from material suitable to satisfy the design.

.7 Portable covers, including the means to lash down such covers, are to be provided.

## 6.4 Gas Turbine Enclosure Ventilation

### 6.4.1 General

In general, the ventilation systems are to comply with the requirements of Part IV of the Rules for Steel Ships and Chapter 13 of the Guidelines.

### 6.4.2 System Requirements

.1 Enclosures or spaces containing turbines using gas or fuel are to be fitted with mechanical exhaust ventilation such that the pressure in the space containing the gas turbine remains negative relative to the pressure in the adjoining spaces while the turbines are operating on the gas mode.

.2 The ventilation fans are to be of non-sparking construction (see 13.3.3 of the Guidelines) and electric motors for these fans are to be located outside of the airflow stream.

.3 The ventilation system is to be designed in order provide effective air circulation and cooling as specified by the turbine manufacturer but is not to be less than 30 air changes per hour based on the volume of the space.

.4 The ventilation system is to be always in operation when the gas turbine is in the gas mode as well as during purging operations prior to maintenance. The gas shut-off valve referred to in 9.4.2 of the Guidelines is to close automatically if the required air flow is not established and maintained by the exhaust ventilation systems.

.5 The ventilation system is to be designed in such a way as to prevent the formation of dead spaces, specifically in the vicinity of electrical equipment, hot surfaces or other potential source of ignition.

.6 The ventilation system is to be entirely separate from all other ventilation systems.

.7 The gas turbine enclosure cooling and ventilation air is to be provided from the weather, unless otherwise approved as per the design.

.8 The inlet cooling and ventilation air calculations or modeling analysis are to be performed and submitted for approval to demonstrate and verify that adequate ventilation capacity is provided for the gas turbine enclosure.

## 6.5 Gas Detection

### 6.5.1 Gas Detection System Requirements

.1 There are to be at least two independent fixed gas detection systems in accordance with 15.8 of the Guidelines and the requirements listed below, fitted in each dual fuel turbine enclosure for continuous monitoring of the presence of leaked gas.

.2 Each gas detection system is to comply with the following requirements:

.1 The gas detection system is to cover all areas of the enclosure or machinery space, where gas is likely to accumulate or where air circulation may be reduced.

.2 Failure of the gas detection system is to cause the gas turbine(s) to changeover to liquid fuel and shutdown all gas fuel sources to the gas turbine engine automatically.

.3 The gas detection system is to be interfaced with the emergency shutdown system as specified in Annex 5/6.5.2.

6.5.2 Gas Detection Set Point

.1 Gas detection system is to be arranged such that at 10% of LEL in the space containing the gas turbine, the gas supply is to be immediately stopped by closing the automatic gas shut-off valve as in 9.4.2 of the Guidelines and the gas turbine is to be automatically changed over to liquid fuel. An audible and visual alarm is to sound to indicate this fault.

.2 If the gas concentration inside the space containing the gas turbine reaches 20% of LEL, then all the fuel supplies to the gas turbine are to be shut off and the space containing gas turbine is to be electrically isolated such that all sources of vapor ignition are removed.

.3 An alternative level of gas concentration to that specified in Annex 5/6.5.2.2 above may be considered based on a gas dissipation study inside the enclosure. Monitoring and safety system functions are to be provided in accordance with Table 15-9 of the Guidelines.

6.6 Fire Protection and Fire Extinguishing System

6.6.1 General

Fire protection and extinguishing systems are to comply with the requirements of Part IX of the Rules for Steel Ships, SOLAS Chapter II-2 and the following requirements:

6.6.2 Fixed Fire Extinguishing Systems

Spaces containing internal combustion machinery, including dual fuel turbines are to comply with Part IX Chapter 8 of the Rules for Steel Ships.

6.6.3 Portable Foam Applicators, Dry Material and Portable Fire Extinguishers

These are to be in compliance with Part IX Chapter 8 of the Rules for Steel Ships.

6.6.4 Fixed Local Application Firefighting Systems

Machinery spaces of Category A above 500 $m^3$ in volume are to be provided with an additional water mist system, complying with the requirements specified in Part IX 8.4.6(b) of the Rules for Steel Ships.

6.6.5 Fire Detection System Requirements

The fire detection system is to comply with the following requirements:

.1 Fire protection arrangements for the one or more gas turbine enclosures or machinery spaces are to be integrated with, and capable of, activation individually or at the same time as, those covering the main machinery spaces.

.2 A fire detection in the gas turbine enclosure is to shut down gas and liquid fuel supply into the enclosure.

# 7 Piping and Auxiliary Systems

7.1 General

.1 Piping systems serving the gas turbine, such as gas fuel, liquid fuel, lubricating oil, starting air/hydraulic and exhaust gas systems are to be in compliance with Part VI of the Rules for Steel Ships, and Chapters 7 and 9 of the Guidelines.

.2 Pipe fabrication, joining details and test requirements are to comply with Chapter 5 of Part XI of the Rules for Steel Ships and Chapter 7 of the Guidelines.

.3 Gas fuel piping is not to pass through accommodation spaces, service spaces or control stations.

.4 All equipment (heaters, compressors, filters, etc.) for making-up the gas for its use as fuel, the related storage tanks and associated piping is to comply with the requirements in Chapters 9 and 10 of the Guidelines.

## 7.2 Gas Fuel Supply Piping System to Gas Turbine

.1 High pressure gas supply lines up to the gas turbine or spaces containing the gas turbine are to be of all-welded construction and adequately protected against impact through falling objects, etc.

.2 Gas fuel piping may pass through or extend into other spaces outside the dual fuel gas turbine enclosure or machinery space, provided they fulfill the requirements of 5.7 and 9.5.

.3 All gas lines are to be capable of being vented and subsequently purged with nitrogen. All nitrogen connections to gas lines with pressures greater than that of the nitrogen purge system are to employ a double block and vent valve arrangement to mitigate the risk of contamination and overpressurizing the nitrogen system.

.4 Where reverse flow of gas supply from gas turbine is possible, a check valve with reverse flow protection is to be provided. This check valve is to be located as close to the gas turbine as practical.

.5 If a gas leak occurs, the gas fuel supply should not be restored to that enclosure or machinery space until the leak has been found and repaired.

## 7.3 Block and Bleed Valve Arrangement

The block and bleed arrangements are to comply with 9.4.4 of the Guidelines.

## 7.4 Gas Shut-off Valve

.1 A gas shut-off valve for the gas turbine enclosure is to be arranged so as to close automatically in accordance with Annex 5/8.3.

.2 After closure of the master gas fuel valve, the block and bleed valve as per Annex 5/7.3 of the Guidelines is to activate.

## 7.5 Gas Compressor

Gas compressors for pressurizing the boil-off gas for the propulsion system are to be designed and tested in accordance with the following:

Compressors are to be suitable for their intended purpose. All equipment and machinery are to be such as to be adequately designed to ensure suitability for use within a marine environment, manufacturer is to submit supporting documentation indicating the equipment has been designed to comply with Chapter 1 of Part IV of the Rules for Steel Ships.

Each size and type of compressor is to be design assessed and prototype tested.

7.5.1 Design Assessment

Gas compressors are to be designed, constructed and tested in accordance with a recognized standard. The standards listed below are considered recognized for the purpose of this section.

- API Std. 617 - Axial and Centrifugal Compressors and Expander-Compressor
- API Std. 618 - Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services
- API Std. 619 - Rotary-type Positive Displacement Compressors for Petroleum, Petrochemical and Natural Gas Industries

Other internationally recognized standards will be considered on a case-by-case basis, provided they are no less effective.

7.5.2 Material Testing

The Surveyor is to verify the materials used in the construction of the compressor against the approved drawings but need not witness the material tests except for those boundary components, with a design temperature below -55℃, whose failure could cause immediate loss of containment of cargo vapor.

7.5.3 Prototype Testing

Prototype testing is to be witnessed by the Surveyor. A certification report documenting the mechanical running and performence tests that were performed will be issued by the attending Surveyor.

.1 Prototype testing is to be consistent with the applicable standard as applied for design assessment and is to include hydrostatic test of the compressor pressure boundary components, mechanical running test and a performance test. Performance tests are to be performed, as a minimum, at full load, rated pressure, temperature and speed.

- The hydrostatic test is to be carried out at a pressure equal to 1.5 times the design pressure and for, at least, 30 minutes.
- The mechanical running test and performance tests should include recording of the gas used, temperatures, pressures, testing of alarms and shut down, pressure relief devices and vibration measurements to ensure that the limits do not exceed those proposed by the manufacturer and that other features relating to the performance of the equipment are in accordance with the specification. Similarly, during the performance test, power consumption and gas loads are to be recorded.
- All critical components as defined by the manufacturer and upon agreement with the Society are to be removed, dismantled, and examined for damage.

.2 The vibration criteria of machinery and equipment are to be provided by manufacturers, consistent with the applicable internationally recognized standard as applied to the design. Otherwise, when the data on the vibration criteria are not available, the following criteria are recommended to be used as a reference in terms of overall Root Mean Square (RMS) value broadband (nominally from 1 to 1000 Hz) or narrowband (nominally from 4 to 200 Hz) for normal operating conditions:

- For reciprocating machinery to be used for continuous operation, the vibration in all directions is to be less than 15 to 25 mm/sec narrowband RMS on the machinery casing or on the structure in the area of bearing depending on whether the machinery is mounted rigidly or flexibly.
- For rotating machinery to be used for continuous operation, the vibration in all directions is to be less than 10 mm/sec broadband overall RMS on the machinery casing or on the structure in the area of bearings.

.3 Alternative limits may be considered on a case-by-case basis. They are to be demonstrated by fatigue calculations, to be submitted for review, defining the analysis method and any engineering assumption made.

#### 7.5.4 Unit Production Testing

Each compressor is to be tested at the plant of manufacture in the presence of the Surveyor. Testing is to include hydrostatic test of the compressor pressure boundary components.

The hydrostatic test is to be carried out at a pressure equal to 1.5 times the design pressure and for, at least, 30 minutes.

#### 7.5.5 Alternative Certification Scheme (ACS)

As an alternative to certification of mass-produced compressors as specified in 7.5.4 above, the manufacturer may request that CR carry out alternative certification scheme (ACS) under the 1.8 of the Guidelines for Suvey of Products for Marine Use. To be design assessed under this program:

.1 The manufacturer may submit drawings based on compliance with recognized standards as specified in 3.2 of the Guidelines for Survey of Products for Marine Use,

.2 A sample of the compressor type is to be subjected to hydrostatic and capacity tests, and relief valve capacity test specified in 7.5.1 and 7.5.2 above. Compressors so assessed may be accepted by CR for listing on CR website,

.3 The manufacturer is to operate a quality assurance system which is to be certified for compliance with a quality standard in accordance with 3.4 of the Guidelines for Survey of Products for Marine Use. The quality control plan is to include provisions to subject each production unit to tests specified in 7.5.4 above. The manufacturer is to submit the record of such tests to the CR who will finalize the Unit Certification. Compressors that meet these requirements will be listed in the CR Product Type Approval Listing.

#### 7.5.6 Compressor Installation

Upon installation on board, the complete compressor assembly connected to the ship systems is to be subjected to a leak test using air or other suitable medium, to a pressure depending on the leak detection method applied. The test is to be performed in the presence of the Surveyor and considered satisfactory if no leaks are observed.

### 7.6 Pressure Vessels, Heat Exchangers and Coolers

Pressure vessels, including storage tanks, separators, vaporizers, heat exchangers, and coolers, etc., are to be designed in accordance with Part V of the Rules for Steel Ships and 6.4.15.3.1 of the Guidelines.

### 7.7 Exhaust Gas Boilers

.1 Exhaust gas boilers are to comply with the requirements of Part V of the Rules for Steel Ships.

.2 Where a composite exhaust gas/fired boiler is arranged to burn fuel gas, it is to comply with the requirements of 10.4 of the Guidelines.

### 7.8 In-duct Burner

.1 In-duct burners using gas and/or liquid fuels are to comply with the requirements of Part V of the Rules for Steel Ships.

.2 They are to be arranged such that the fired section of the ducting can be cleared of combustible vapors and provided with suitable charge of air to support safe and efficient combustion prior to operation.

# 8 Electrical, Automation, Instrumentation and Control Systems

## 8.1 General

.1 Electrical equipment for the dual fuel turbine gas propulsion system is to comply with the applicable requirements of Chapter 14 of the Guidelines.

.2 The instrumentation, monitoring and control systems for gas turbine engines are to comply with the applicable requirements of Part VIII of the Rules for Steel Ships, and all associated electrical systems are to comply with the requirements of Chapter 14 of the Guidelines.

## 8.2 Electrical Equipment

.1 Electrical equipment which may create an electrical spark, such as magnetic contactors, circuit breakers, motor starters, switchboards, slip rings or commutators, is to be located outside of the dual fuel gas turbine engine enclosure or machinery space containing the gas turbine unless fuel gas piping is in full compliance with 9.6 of the Guidelines.

.2 All electronic and electrical equipment in the dual fuel gas turbine enclosure, which is intended to be operational after the dual fuel turbine engines have been shut down due to leakage is to be of certified safe type.

## 8.3 Alarm and Shutdown System

### 8.3.1 Automatic Shut-off of Gas Turbine and Fuel Supply

.1 The monitoring and safety system functions for dual fuel gas turbine and gas fuel supply systems are to be provided in accordance with 10.5.7 and Table 15-9 of the Guidelines. Propulsion machinery using methane as fuel and intended for automatic operation or operation from a remote control station are to comply with the applicable requirements in Chapter 4 of Part VIII of the Rules for Steel Ships.

Means are to be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply is to be shut down.

.2 An alarm(s) is to be provided at the gas turbine engine control station. In addition, a summary alarm(s) is to be provided at the navigation bridge.

# *CHAPTER 11 FIRE SAFETY*

## *11.1 Goal*

*The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of natural gas as ship fuel.*

## *11.2 Functional Requirements*

*This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17 of the Guidelines.*

## *11.3 Regulations for Fire Protection*

*11.3.1 Any space containing equipment for the fuel preparation such as pumps, compressors, heat exchangers, vaporizers and pressure vessels shall be regarded as a machinery space of category A for fire protection purposes.*

IACS Interpretation of 11.3.1

.1 Fire protection in 11.3.1 means structural fire protection, not including means of escape.

.2 Enclosed spaces containing equipment for fuel preparation such as pumps or compressors or other potential ignition sources are to be provided with a fixed fire-extinguishing system complying with the provisions of SOLAS II-2/10.4.1.1 and the FSS Code and taking into account the necessary concentrations / application rate required for extinguishing gas fires.

*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.*

*11.3.3 The space containing the 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 the 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.*

*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*

CR Interpretation of 11.3.3

It is understood that tank connection spaces and ventilation trunks to tank connection spaces are to be insulated to class A-60. However, where the tank connection spaces and ventilation trunks are adjacent to spaces with lower fire risks, the tank connection space and ventilation trunk to tank connection spaces are to be considered as a machinery space of category A, in order to determine the insulation in accordance with SOLAS regulation II-2/9.

IACS Interpretation of 11.3.3
The following "other rooms with high fire risk" should as a minimum be considered, but not be restricted to:

(a) 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;

(b) vehicle, ro-ro and special category spaces;

(c) service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and storerooms having areas of 4 $m^2$ 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

(d) 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 $m^2$ or more, as provided in SOLAS regulation II-2/9.2.2.3.

*11.3.4 The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk.*

*11.3.5 The fire protection of fuel pipes led through ro-ro spaces shall be subject to special consideration by the Administration depending on the use and expected pressure in the pipes.*

*11.3.6 The bunkering station shall be separated by A-60 class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.*

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

## *11.4 Regulations for Fire Main*

*11.4.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.*

*11.4.2 When the fuel storage tank(s) is located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section from the supply of water.*

## *11.5 Regulations for Water Spray System*

*11.5.1 A water spray system shall be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck.*

*11.5.2 The water spray system shall also provide coverage for boundaries of the superstructures, compressor rooms, pump-rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks unless the tank is located 10 metres or more from the boundaries.*

*11.5.3 The system shall be designed to cover all areas as specified above with an application rate of 10 l/min/m$^2$ for the largest horizontal projected surfaces and 4 l/min/m$^2$ for vertical surfaces.*

*11.5.4 Stop valves shall be fitted in the water spray application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.*

*11.5.5 The capacity of the water spray pump shall be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.*

*11.5.6 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve shall be provided.*

*11.5.7 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system shall be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.*

*11.5.8 The nozzles shall be of an approved full bore type and they shall be arranged to ensure an effective distribution of water throughout the space being protected.*

## *11.6 Regulations for Dry Chemical Powder Fire-Extinguishing System*

*11.6.1 A permanently installed dry chemical powder fire-extinguishing system shall be installed in the bunkering station area to cover all possible leak points. The capacity shall be at least 3.5 kg/s for a minimum of 45 s. The system shall be arranged for easy manual release from a safe location outside the protected area.*

*11.6.2 In addition to any other portable fire extinguishers that may be required elsewhere in IMO instruments, one portable dry powder extinguisher of at least 5 kg capacity shall be located near the bunkering station.*

## *11.7 Regulations for Fire Detection and Alarm System*

*11.7.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code shall be provided for the fuel storage hold spaces and the ventilation trunk for fuel containment system below deck, and for all other rooms of the fuel gas system where fire cannot be excluded.*

CR Interpretation of 11.7.1

It is understood that the reference to the ventilation trunk for fuel containment system below deck in 11.7.1 above means that a fire detection and alarm system is to be provided in the ventilation trunk to the tank connection space and in the tank connection space.

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

## *11.8 Regulation for 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.*

# *CHAPTER 12 EXPLOSION PREVENTION*

## *12.1 Goal*

*The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.*

## *12.2 Functional Requirements*

*This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17 of the Guidelines. In particular the following apply:*

*The probability of explosions shall be reduced to a minimum by:*

*.1 reducing number of sources of ignition; and*

*.2 reducing the probability of formation of ignitable mixtures.*

## *12.3 Regulations – General*

*12.3.1 Hazardous areas on open deck and other spaces not addressed in this chapter shall be decided based on a recognized standard.[19] The electrical equipment fitted within hazardous areas shall be according to the same standard.*

*12.3.2 Electrical equipment and wiring shall in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard.[20]*

*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.*

CR Interpretation of 12.3.3
Electrical equipment, which may create an electrical spark, such as magnetic contactors, circuit breakers, motor starters, switchboards, slip rings or commutators, is to be located outside of the ESD-protected machinery spaces.

*Note 19:*
*Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.*

*Note 20:*
*Refer to IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.*

12.3.4 (CR) Explosion Protection, ESD-Protected Machinery Spaces

Arrangements are to be such that effects of an explosion in a ESD-protected machinery spaces can be contained or vented and will not cause damage to any space other than that in which the incident occurs nor render machinery or equipment in other spaces inoperable. Such incidents should also not cause damage that would under normal operating conditions, injure people in work areas, accommodation, service spaces, or control stations.

## *12.4 Regulations on Area Classification*

*12.4.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.*

*12.4.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2.[21] See also 12.5 below.*

*12.4.3 Ventilation ducts shall have the same area classification as the ventilated space.*

## *12.5 Hazardous Area Zones*

*12.5.1 Hazardous area zone 0*

*This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.*

*12.5.2 Hazardous area zone 1[22]*

*This zone includes, but is not limited to:*

*.1 tank connection spaces, fuel storage hold spaces[23] and interbarrier spaces;*

*.2 fuel preparation room arranged with ventilation according to 13.6 of the Guidelines;*

*.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet,[24] bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;*

*.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;*

*Note 21:*

*Refer to standards IEC 60079-10-1:2008 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.*

*Note 22:*

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

*Note 23:*

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

.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;*

(CR)

Including gas valve unit (GVU)/gas valve train (GVT) spaces or enclosures;

.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.*

(IACS)

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.

Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they shall be considered hazardous area zone 1.

Where the fuel storage hold spaces include bolted access to the tank connection space, they shall be considered hazardous area zone 2.

*12.5.3 Hazardous area zone 2*[(25)]

*12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.*

*12.5.3.2 Space containing bolted hatch to tank connection space.*

12.5.3.3 (CR)

The interiors of auxiliary system circuit expansion/header tanks and areas within 1.5 m of said tank vent outlets: where these circuits are likely to contain gas under normal or abnormal operating conditions, see 10.3.1.4 and 9.10.4 of the Guidelines.

*Note 24:*

*Such areas are, for example, all areas within 3 m of fuel tank hatches, ullage openings or sounding pipes for fuel tanks located on open deck and gas vapour outlets.*

(CR)

Including any crankcase vent outlet from engines operating according to the Otto cycle;

*Note 25:*

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

# *CHAPTER 13 VENTILATION*

## *13.1 Goal*

*The goal of this chapter is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.*

## *13.2 Functional Requirements*

*This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17 of the Guidelines.*

## *13.3 Regulations – General*

*13.3.1 Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces. The ventilation shall function at all temperatures and environmental conditions the ship will be operating in.*

*13.3.2 Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.*

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

*.1 Ventilation fans shall not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, shall be of non-sparking construction defined as:*

- *.1 impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;*
- *.2 impellers and housings of non-ferrous metals;*
- *.3 impellers and housings of austenitic stainless steel;*
- *.4 impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or*
- *.5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.*

*.2 In no case shall the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.*

*.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.*

*13.3.4 Ventilation systems required to avoid any gas accumulation shall consist of independent fans, each of sufficient capacity, unless otherwise specified in the IGF Code.*

*13.3.5 Air inlets for hazardous enclosed spaces shall be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct shall be gas-tight and have over-pressure relative to this space.*

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

*13.3.7 Air outlets from hazardous enclosed spaces shall be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.*

*13.3.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.*

*13.3.9 Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation shall be arranged according to the following:*

*.1 During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it shall be required to:*

*.1 proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and*

*.2 pressurize the space.*

*.2 Operation of the overpressure ventilation shall be monitored and in the event of failure of the overpressure ventilation:*

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

*.2 if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard[(26)] shall be required.*

*13.3.10 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an airlock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space shall be monitored and in the event of failure of the extraction ventilation:*

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

*.2 if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space shall be required.*

## *13.4 Regulations for Tank Connection Space*

*13.4.1 The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment.*

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

*Note 26:*
*Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, Table 5.*

## 13.5 Regulations for Machinery Spaces

*13.5.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems.*

Interpretation of 13.5.1

.1 (CR)
The ventilation system for an ESD-protected machinery space is to be always in operation when there is gas fuel in the piping while in normal operation, as well as in purging operation prior to maintenance works.

.2 (CR)
The forced ventilation is to be arranged in the ESD-protected machinery space in such a manner that immediate evacuation of the leaked gas from the entire space occurs without the possibility of pockets of gas remaining in isolated corners.

Either a gas dispersion analysis or a physical smoke test under the possible operating modes is to be conducted in order to prove that the inlets in the ducting are strategically positioned for the effective removal of the leaked gas from the space.

.3 (IACS)
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 machinery space ventilation system.

*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.*

CR Interpretation of 13.5.2
Any proposal to reduce the ventilation capacity below 30 air changes per hour as mentioned in 13.5.2 above would be subject to special consideration in association with a risk assessment in accordance with 4.2 of the Guidelines covering ventilation of the machinery space.

*13.5.3 For ESD protected machinery spaces the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard acceptable to the Organization.*[27]

*13.5.4 The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms shall be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.*

CR Interpretation of 13.5.4
The number and power of the ventilation fans for ESD-protected machinery spaces should be such that if one fan, or a group of fans with common circuit from the main switchboard or emergency switchboard, are out of service the capacity of the remaining ventilation fan(s) is not to be less than 100% of the total required.

*Note 27: Refer to IEC 60079-10-1.*

## *13.6 Regulations for Fuel Preparation Room*

*13.6.1 Fuel preparation rooms, shall be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.*

*13.6.2 The number and power of the ventilation fans shall be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.*

CR Interpretation of 13.6.2

The number and power of the ventilation fans for fuel preparation rooms is to be such that if one fan, or a group of fans with common circuit from the main switchboard or emergency switchboard, are out of service the capacity of the remaining ventilation fan(s) is not to be less than 100% of the total required.

*13.6.3 Ventilation systems for fuel preparation rooms, shall be in operation when pumps or compressors are working.*

## *13.7 Regulations for Bunkering Station*

*Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1 of the Guidelines.*

## *13.8 Regulations for Ducts and Double Pipes*

*13.8.1 Ducts and double pipes containing fuel piping shall be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not applicable to double pipes in the engine-room if fulfilling 9.6.1.1 of the Guidelines.*

*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.*

IACS Interpretation of 13.8.2

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.

*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.*

CR Interpretation of 13.8.3

The ventilation outlet for the double wall piping or duct is to be in accordance with 9.6.1.2 of the Guidelines.

IACS Interpretation of 13.8.3

The ventilation inlet for the double wall piping or duct is to always be located in a non-hazardous area in open air away from ignition sources.

*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.*

# *CHAPTER 14 ELECTRICAL INSTALLATIONS*

## *14.1 Goal*

*The goal of this chapter is to provide for electrical installations that minimizes the risk of ignition in the presence of a flammable atmosphere.*

## *14.2 Functional Requirements*

*This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18 of the Guidelines. In particular the following apply:*

*Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.*

## *14.3 Regulations – General*

*14.3.1 Electrical installations shall be in compliance with a standard at least equivalent to those acceptable to the Organization.(28)*

*14.3.2 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.*

*14.3.3 Where electrical equipment is installed in hazardous areas as provided in 14.3.2 above it shall be selected, installed and maintained in accordance with standards at least equivalent to those acceptable to the Organization.(29) Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.*

*14.3.4 Failure modes and effects of single failure for electrical generation and distribution systems in 14.2 of the Guidelines shall be analysed and documented to be at least equivalent to those acceptable to the Organization.(30)*

*14.3.5 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be located in a non-hazardous area.*

*14.3.6 The installation on board of the electrical equipment units shall be such as to ensure the safe bonding to the hull of the units themselves.*

*Note 28: Refer to IEC 60092 series standards, as applicable.*

*Note 29:Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.*

*Note 30: Refer to IEC 60812.*

*14.3.7 Arrangements shall be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.*

*14.3.8 Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.*

*14.3.9 For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type shall be de-energized upon loss of overpressure in the space.*

*14.3.10 Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, shall be of a certified safe type.*

# *CHAPTER 15 CONTROL, MONITORING AND SAFETY SYSTEMS*

## *15.1 Goal*

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

## *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 of the Guidelines. 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 Table15-1 of the Guidelines and upon other fault conditions which may develop too fast for manual intervention;*

CR Interpretation of 15.2.3

The fuel gas supply system is also to automatically close down, upon failure in systems as described in Table 15-5, Table 15-8 and Table 15-9 of the Guidelines, as applicable.

*.3 for ESD protected machinery configurations the safety system shall shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;*

*.4 the safety functions shall be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;*

*.5 the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and*

*.6 where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent gas control and gas safety systems.*

## *15.3 Regulations – General*

*15.3.1 Suitable instrumentation devices shall be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.*

*15.3.2 A bilge well in each tank connection space of an independent liquefied gas storage tank shall be provided with both a level indicator and a temperature sensor. Alarm shall be given at high level in the bilge well. Low temperature indication shall activate the safety system.*

IACS Interpretation of 15.3.2

The "level indicator" required by 15.3.2 above 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.

*15.3.3 For tanks not permanently installed in the ship a monitoring system shall be provided as for permanently installed tanks.*

## *15.4 Regulations for Bunkering and Liquefied Gas Fuel Tank Monitoring*

*15.4.1 Level indicators for liquefied gas fuel tanks*

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

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

*.3 Liquefied gas fuel tank liquid level gauges may be of the following types:*

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

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

*15.4.2 Overflow control*

*.1 Each liquefied gas fuel tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.*

*.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the liquefied gas fuel tank from becoming liquid full.*

*.3 The position of the sensors in the liquefied gas fuel tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high level alarms shall be conducted by raising the fuel liquid level in the liquefied gas fuel tank to the alarm point.*

*.4 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to fuel operation in accordance with 18.4.3 of the Guidelines.*

*.5 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated continuous visual indication is to be provided at the navigation bridge, continuously manned central control station or onboard safety centre.*

*15.4.3 The vapour space of each liquefied gas fuel tank shall be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control station or onboard safety centre.*

*15.4.4 The pressure indicators shall be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.*

*15.4.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms shall be activated before the set pressures of the safety valves are reached.*

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

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

*15.4.8 Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indicator.*

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

*15.4.10 For submerged fuel-pump motors and their supply cables, arrangements shall be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.*

*15.4.11 Except for independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank shall be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.*

15.4.12 (CR)

The temperature indicating devices required by 15.4.11 above are to be capable of providing temperature indication across the expected operating temperature range of the tanks.

Where thermowells are fitted they are to be designed so that failure will not occur due to fatigue in normal service.

## *15.5 Regulations for Bunkering Control*

*15.5.1 Control of the bunkering shall be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by 15.4.11 above, and tank level shall be monitored. Remotely controlled valves required by 8.5.3 and 11.5.7 of the Guidelines shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location.*

*15.5.2 If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm shall be provided at the bunkering control location, see also 15.8 of the Guidelines.*

CR Interpretation of 15.5.2

Where bunkering lines are enclosed in double pipes or ducts, the ventilation is to always be in operation during bunkering operations.

*15.5.3 If gas is detected in the ducting around the bunkering lines an audible and visual alarm and emergency shutdown shall be provided at the bunkering control location.*

15.5.4 (CR)

.1 The bunkering control system is to incorporate an emergency shutdown facility to stop bunker flow in the event of an emergency. The design of the ESD system is to avoid the potential generation of surge pressures within bunker transfer pipe work.

.2 The ESD is to be activated by the manual and automatic inputs listed in Table 15-3.

.3 A functional flow chart of the bunkering control system and ESD functions are to be provided in the fuel bunkering control station and on the bridge.

.4 The ESD function is to operate the remote valve required by 8.5.3 of the Guidelines.

.5 As a minimum, the ESD action is to be capable of manual operation by a single control on the bridge, the safe control position required by 15.5.1 above and at least two strategic positions around the bunker manifold area.

## *15.6 Regulations for Gas Compressor Monitoring*

*15.6.1 Gas compressors shall be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms shall include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.*

CR Interpretation of 15.6.1

LNG pumps are to be fitted with audible and visual alarms both on the bridge and at the control station. As a minimum the alarms are to indicate low LNG discharge pressure, high LNG inlet temperature, high LNG discharge pressure and LNG pump operation.

*15.6.2 Temperature monitoring for the bulkhead shaft glands and bearings shall be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.*

CR Interpretation of 15.6.2

15.6.2 above is also applicable to LNG pumps driven by shafts passing through gas tight bulkheads.

15.6.3 (CR)

The gas compressor monitoring system is to include anti surge protection.

## 15.7 Regulations for Gas Engine Monitoring

*In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators shall be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:*

*.1 operation of the engine in case of gas-only engines; or*

*.2 operation and mode of operation of the engine in the case of dual fuel engines.*

CR Interpretation of 15.7
Engine Control and Monitoring Systems

(a) Where additional features such as hydraulic control circuits or sealing systems form part of the systems for safe operation of the engine, the loss of actuating power in these systems is to cause automatic shutdown of the fuel gas supply system.

Where these systems incorporate external high pressure piping of flammable liquids then these are to be protected with a jacketed piping system capable of containing leakage from the high pressure pipe and arranged for leakage collection and alarm as follows:

All external high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. Metallic hose of approved design may be accepted as the outer pipe, where outer piping flexibility is required for the manufacturing process of the permanent assembly. The jacketed piping system is to include means for collection of leakages, and arrangements are to be provided for an alarm to be given of a fuel line failure.

(b) Unless the FMEA proves otherwise, the monitoring and safety system functions for the engines are to be provided in accordance with Table 15-8 of the Guidelines, as applicable.

(c) The alarms required by Table 15-8 of the Guidelines are to be provided at tthe engine control station. In addition, a summary alarm is to be provided at the navigation bridge.

## 15.8 Regulations for Gas Detection

*15.8.1 Permanently installed gas detectors shall be fitted in:*

*.1 the tank connection spaces;*

*.2 all ducts around fuel pipes;*

*.3 machinery spaces containing gas piping, gas equipment or gas consumers;*

*.4 compressor rooms and fuel preparation rooms;*

*.5 other enclosed spaces containing fuel piping or other fuel equipment without ducting;*

*.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;*

*.7 airlocks;*

*.8 gas heating circuit expansion tanks;*

*.9 motor rooms associated with the fuel systems; and*

*.10 or at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2 of the Guidelines.*

*15.8.2 In each ESD-protected machinery space, redundant gas detection systems shall be provided.*

*15.8.3 The number of detectors in each space shall be considered taking into account the size, layout and ventilation of the space.*

*15.8.4 The detection equipment shall be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test shall be used to find the best arrangement.*

CR Interpretation of 15.8.4

Placement of the detectors is critical to the effectiveness of the gas detection system. The exact location of the gas detectors is to be determined taking into consideration the sensitivity of the gas detectors under the prevailing airflow. Arrangements will be subject to approval for each application based upon the gas dispersion analysis or the physical smoke test.

*15.8.5 Gas detection equipment shall be designed, installed and tested in accordance with a recognized standard.*[(31)]

*15.8.6 An audible and visible alarm shall be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system shall be activated at 40% of LEL at two detectors (see footnote 1 in Table15-1 of the Guidelines).*

*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 Table15-1 of the Guidelines).*

*15.8.8 Audible and visible alarms from the gas detection equipment shall be located on the navigation bridge or in the continuously manned central control station.*

*15.8.9 Gas detection required by this Chapter shall be continuous without delay.*

15.8.10 (CR)

Gas detection systems are to be of the self-monitoring type.

*Note 31:*

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

15.8.11 (CR)

In the event that a system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected such that the detector fault will not cause false emergency shutdown.

15.8.12 (CR)

The gas detection equipment is to be designed so that it may be readily tested.

15.8.13 (CR)

The gas detection system is always to be in operation when there is gas fuel in the piping, during normal operation and whilst purging prior to maintenance works.

## *15.9 Regulations for Fire Detection*

*Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in Table15-1 of the Guidelines.*

## *15.10 Regulations for Ventilation*

*15.10.1 Any loss of the required ventilating capacity shall give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre.*

IACS Interpretation of 15.10.1

Acceptable means to confirm that the ventilation system has the "required ventilating capacity" in operation are, but not limited to:

Monitoring of the ventilation electric motor or fan operation combined with underpressure indication ; or

Monitoring of the ventilation electric motor or fan operation combined with ventilation flow indication ; or

Monitoring of ventilation flow rate to indicate that the required air flow rate is established.

*15.10.2 For ESD protected machinery spaces the safety system shall be activated upon loss of ventilation in engine-room.*

## *15.11 Regulations on Safety Functions of Fuel Supply Systems*

*15.11.1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply shall not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect shall be placed at the operating station for the shutoff valves in the fuel supply lines.*

*15.11.2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply shall not be operated until the leak has been found and dealt with. Instructions to this effect shall be placed in a prominent position in the machinery space.*

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

CR Interpretation of 15.11.3

The requirement from 15.11.3 above also applies to machinery spaces and fuel preparation rooms containing other consumers or fuel preparation equipment.

*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.*

15.11.5 (CR)

Indications of parameters necessary for the safe and effective operation of the fuel supply system process are to be provided, as per Table15-4 and Table15-5.

***Table 15-1 Monitoring of Gas Supply System to Engines***

| *Parameter* | *Alarm* | *Automatic shutdown of tank valve [(6)]* | *Automatic shutdown of gas supply to machinery space containing gas-fuelled engines* | *Comments* |
|---|---|---|---|---|
| *Gas detection in tank connection space at 20% LEL* | *X* | | | |
| *Gas detection on two detectors[(1)]in tank connection space at 40% LEL* | *X* | *X* | | |
| *Fire detection in fuel storage hold space* | *X* | | | |
| *Fire detection in ventilation trunk for fuel containment system below deck* | *X* | | | |
| *Bilge well high level in tank connection space* | *X* | | | |
| *Bilge well low temperature in tank connection space* | *X* | *X* | | |
| *Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL* | *X* | | | |
| *Gas detection on two detectors [(1)]in duct between tank and machinery space containing gas-fuelled engines at 40% LEL* | *X* | *X[(2)]* | | |
| *Gas detection in fuel preparation room at 20% LEL* | *X* | | | |
| *Gas detection on two detectors [(1)]in fuel preparation room at 40% LEL* | *X* | *X [(2)]* | | |
| *Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL* | *X* | | | *If double pipe fitted in machinery space containing gas-fuelled engines* |
| *Gas detection on two detectors [(1)]in duct inside machinery space containing gas-fuelled engines at 60% LEL* | *X* | | *X [(3)]* | *If double pipe fitted in machinery space containing gas-fuelled engines* |
| *Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL* | *X* | | | |
| *Gas detection on two detectors [(1)] in ESD protected machinery space containing gas-fuelled engines at 40% LEL* | *X* | | *X* | *It shall also disconnect non-certified safe* |

| *Parameter* | *Alarm* | *Automatic shutdown of tank valve* (6) | *Automatic shutdown of gas supply to machinery space containing gas-fuelled engines* | *Comments* |
|---|---|---|---|---|
| | | | | *electrical equipment in machinery space containing gas-fuelled engines* |
| *Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines* | *X* | | *X* (2) | |
| *Loss of ventilation in duct inside machinery space containing gas-fuelled engines* (5) | *X* | | *X* (3) | *If double pipe fitted in machinery space containing gas-fuelled engines* |
| *Loss of ventilation in ESD protected machinery space containing gas-fuelled engines* | *X* | | *X* | |
| *Fire detection in machinery space containing gas-fuelled engines* | *X* | | | |
| *Abnormal gas pressure in gas supply pipe* | *X* | | | |
| *Failure of valve control actuating medium* | *X* | | *X* (4) | *Time delayed as found necessary* |
| *Automatic shutdown of engine (engine failure)* | *X* | | *X*(4) | |
| *Manually activated emergency shutdown of engine* | *X* | | *X* | |

*Notes:*

*(1) 2 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 gas fuel valves fitted outside of the duct, only the master gas fuel 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 gas fuel valves fitted outside of the duct and outside of the machinery space containing gasfuelled engines, only the master gas fuel valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.*

*(4) Only double block and bleed valves to close.*

*(5) If the duct is protected by inert gas (see 9.6.1.1 of the Guidelines) 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. of the Guidelines.*

**Table 15-2**
**(CR) Monitoring and Safety System Functions for Fuel Tanks**

| Monitored Parameters | Alarm | Automatic Shutdown of theTank Valves |
|---|---|---|
| High or low liquid level in fuel tank (1) | X | |
| Low-low liquid level in fuel tanks with submerged electric pumps(4) | X | |
| High or low pressure in fuel tank | X | |
| High or low temperature in fuel tank | X | |
| Fire detection in tank connection space or ventilation trunk to tank connection space (2) | X | X |
| Leakage from primary barrier (3) | X | |

Notes:
(1) Overflow protection for tank to be by independent high liquid level alarm in accordance with 15.4.2 of the Guidelines and low liquid level protection for the tank to 14.3.7 of the Guidelines.
(2) Ventilation is to be stopped and fire dampers closed automatically, see 13.4.2 of the Guidelines
(3) For fuel containment systems requiring a full or partial secondary barrier, see 6.4.5 of the Guidelines.
(4) Submerged electric pumps are to automatically shut down on low-low liquid level in gas fuel tanks, see 15.4.10 of the Guidelines.

**Table 15-3**
**(CR) Monitoring and Safety System Functions for Fuel Bunkering System**

| Monitored Parameters | Alarm | Automatic Shutdown of the Manifold ESD Valves (1) |
|---|---|---|
| Gas detection at enclosed or semi-enclosed bunker station above 20% LEL | X | |
| Gas detection at enclosed or semi-enclosed bunker station above 40% LEL | X | X |
| Fire detection in tank connection space or fuel preparation rooms | X | X |
| Loss of ventilation in ducting around the bunkering lines | X | |
| Gas detection in ducting around bunkering lines above 20% LEL | X | |
| Gas detection in ducting around bunkering lines above 40% LEL | X | X |
| Independent high liquid level in fuel tank (2) | X | X |
| High pressure in fuel tank | X | X |
| Manual ESD shutdowns | X | X |
| Manual or automatic ESD signal from bunker supplier | X | X |
| Loss of ESD valve motive power (3) | X | X |

Notes:
(1) ESD signal and automatic activation of the ESD valves on the bunker receiving ship to activate automatic shutdown of the ESD valves and supply pumps at the bunker supplier.
(2) This independent high liquid level alarm and automatic shutdown of the bunker manifold ESD valves is at the operating signal level referenced by 16.7.3.7.
(3) Manifold ESD valves are to be of fail closed type as per 8.5.3.

**Table 15-4**
**(CR) Instrumentation and Alarms for Gas Compressors and LNG Pumps**

| Item | | Display | Alarm Activated | Automatic Shut Down |
|---|---|---|---|---|
| BOG Compressor | Driving motors | Running | Stop | |
| | LO Temperature | | High | |
| | LO Pressure | | Low | |
| | Sealing gas pressure, if applicable | | Low | |
| | Control air pressure loss, ifapplicable | | Failed | X |
| LNG Pumps | Driving motors | Running | Stop | |

**Table 15-5**
**(CR) Monitoring and Safety System Functions for Fuel Gas Supply System**

| Monitored Parameters | Alarm | Automatic Shutdown of the Tank Valves | Automatic Shutoff of the Master Gas Fuel Valve and Automatic Activation of the Block and Bleed Valves | Automatic Engine Shutdown |
|---|---|---|---|---|
| Gas detection in machinery space containing gas consumer above 20% LEL | X | | | |
| Gas detection in machinery space containing gas consumerabove 40% LEL | X | | X | |
| Gas detection in machinery space containing gas consumerabove 60% LEL (1) | X | | X | X |
| Gas detection in enclosed spaces outside of machinery spaceswith fuel gas supply piping or equipment above 20% LEL (2) | X | | | |
| Gas detection in enclosed spaces outside of machinery spaceswith fuel gas supply piping or equipment above 40% LEL (2) | X | X | X | |
| Gas detection in auxiliary heat exchange circuit header tank (3) | X | | | |
| Loss of ventilation in fuel preparation room | X | | | |
| Rapid detection of gas supply rupture (4) | X | | X | |

Notes:
(1) See 9.4.15 of the Guidelines.
(2) For ducted piping in enclosed spaces outside of machinery spaces. See 9.5.1 and 15.8.1.3 of the Guidelines.
(3) See 9.4.14 of the Guidelines.
(4) For high pressure installations and ESD-protected machinery spaces only, see 9.4.10 of the Guidelines.

**Table 15-6**
**(CR) Instrumentation and Alarms in Centralized Control Stations for the Reliquefaction Systems**

| Item | | | Display | Alarm Activated | Automatic Shut Down |
|---|---|---|---|---|---|
| BOG Compressor | Flow rate | | X | Low | X (Low-Low) |
| BOG Compressor | Driving motors | | Running | Stop | |
| BOG Compressor | LO Temperature | | | High | |
| BOG Compressor | LO Pressure | | | Low | |
| BOG Compressor | Seperator level, if fitted | | X | High | |
| BOG Compressor | Suction line | Pressure | X | High/Low | X (High-High) |
| BOG Compressor | Suction line | Temperature | X | High | X (High-High) |
| BOG Compressor | Discharge line | Pressure | X | Low | X (Low-Low) |
| BOG Compressor | Discharge line | Temperature | X | High/Low | X (High-High) |
| BOG Compressor | Gas Detection in cold box | | | X(20% LEL) | X (40% LEL) |
| BOG Compressor | Cryogenic heat exchanger inlet temperature | | X | High | X (High-High) |
| Refrigerating Compressor | Lubricating oil temperature | | X | High | X (High-High) |
| Refrigerating Compressor | Driving motors | | Running | Stop | |
| Refrigerating Compressor | Inlet | Pressure | X | Low | X (Low-Low) |
| Refrigerating Compressor | Inlet | Temperature | X | High/Low | X (High-High) |
| Refrigerating Compressor | Discharge line | Pressure | X | High | X (High-High) |
| Refrigerating Compressor | Discharge line | Temperature | X | High/Low | |
| Refrigerating Compressor | Seal gas pressure | | X | Low | X (Low-Low) |
| Refrigerating Compressor | Seal gas leakage expander pressure | | X | High | X (High-High) |
| Machinery Spaces Containing Refrigeration Equipment | Containing Refrigeration Equipment Oxygen Level Detection System | | X | Low | |
| Machinery Spaces Containing Refrigeration Equipment | Refrigerant Concentration Detection System, if Considered Toxic | | X | High | |

**Table 15-7**
**(CR) Instrumentation and Alarms in Centralized Control Station for the GCU**

| Item | | Display | Alarm | Automatic Shut Down |
|---|---|---|---|---|
| Gas valves enclosure | Gas detection | | 20% LEL | 40% LEL |
| | BOG flow rate | X | Low | X (Low-Low) |
| | BOG temperature | X | Low | |
| | Ventilation fan | Running | Stopped | X (failure) |
| Gas valve train | Compressor pressure | X | High | X (High-High) |
| | Discharge line temperature | X | High/Low | X (High-High) |
| Oxidizing Unit and burner casing | Combustion Fan | Running | Stopped/stand by auto start | |
| | Dilution fan | Running | Stopped/stand by auto start | |
| | Flame scanner | | X | Failed |
| | Burner flame | | X | Failed |
| | Furnace temperature | | High | |
| | Fire or high temperature in fluegas section | X | High | X (High-High) |
| | Gas fuel pressure | X | Low | X (Low-Low) |
| | Gas fuel temperature | | High/Low | X (HH/LL) |
| Burner Management and Control System | Control power supply | | Failed | |
| | Emergency Shutdown | | X | |

**Table 15-8**
**(CR) Monitoring and Safety System Functions for Engines**

| Monitored Parameters | Alarm | Automatic Activation of the Block and Bleed Valves | Automatic Switching Over to Oil Fuel Mode (1) | Automatic Engine Slowdown /Shutdown |
|---|---|---|---|---|
| Fuel gas supply systems – malfunction | X | X | X | |
| Pilot oil fuel injection or spark ignition systems – malfunction | X | X | X | |
| Exhaust gas after each cylinder, temperature – high | X | X | X | |
| Exhaust gas after each cylinder, deviation fromaverage, temperature – high | X | X | X | |
| Cylinder pressure or ignition – failure, includingmisfire and knocking | X | X | X | |
| Oil mist in crankcase, mist concentration | X | X | | X (3) |
| Engine stops – any cause | X | X | | |
| Failure of the control-actuating medium of theblock and bleed valves | X | X | X | |
| Failure of the control-actuating medium of the gasvalves, as applicable | X | X | X | |
| Failure of the gas valve oil sealing system, asapplicable | X | X | X | |
| Gas detection in auxiliary heat exchange circuitheader tank (2) | X | | | |

Notes:
(1) Duel Fuel Diesel engines only
(2) See 10.3.1.4 of the Guidelines.
(3) Auto slow-down for slow speed engines and auto shutdown for medium and high speed engines.

**Table 15-9**
**(CR) Monitoring and Safety System Functions for Dual Fuel Gas Turbine and Supply Systems**

| Monitored Parameters | Alarm | Automatic Shut-off of the Individual Master Gas Fuel Valve and Automatic Activation of the Block and Bleed Valves | Automatic Switching over to Oil Fuel Mode | Enclosure/Mach. Space Shutdown (see Annex 5/8.3.1 of the Guidelines) |
|---|---|---|---|---|
| Gas Turbine High Exhaust Temperature – High | X | | | |
| Gas Turbine High Exhaust Temperature – High-High | | X | | |
| Gas Turbine Bearing metal chip detector | X | | | |
| Gas detection at 10% LEL | X | X | X | |
| Incorrect combustion | X | X | X | |
| Loss of ventilation for the gas turbine engine space | X | X | X | |
| Low pressures in the gas fuel supply line | X | X | X | |
| Failure of the control-actuating medium of the master/ESD gas fuel valve | X | X | X | |
| Failure of gas detection system | X | X | X | |
| Loss of airflow in the space between gas fuel pipe and ventilated pipe or duct, as specified in Annex 5/6.4.2, if fitted | X | X | X | |
| Fire detection in the turbine enclosure | X | X | | X |
| Gas detection at 20% LEL | X | X | | X |
| Vibration – High | X | X | | |
| Vibration – High-High | X | X | | |

# *CHAPTER 16 MANUFACTURE, WORKMANSHIP AND TESTING*

Note:
The IGF Code PART B-1 is incorporated into Chapter 16 of the Guidelines.

***PART B-1***

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

## *16.1 General*

*16.1.1 The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the regulations given in the IGF Code.*

CR Interpretation of 16.1.1

Testing of plating, rolled sections, pipes, process pressure vessels, valves, forgings, castings.

Test and Test Data

Witness Test. The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved in accordance with 1.8 of CR Guidelines for Survey of Products for Marine Use.

Manufacturer's Data. The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

Symbols：

－ Applicable(X);

| Types | Product name | Witness Test | Manufacturer's Data | Notes |
|---|---|---|---|---|
| Fuel Tanks. (Types A, B and C) & Process Pressure Vessels | | | | |
| A. | Plating | X | | |
| B. | Rolled Sections | X | | |
| C. | Castings & Forgings | X | | |
| D. | Membrane | X | | Tension test only |
| Secondary Barriers (Metallic) | | | | |
| A. | Membrane | X | | Tension test only |
| B. | Plates & Rolled Sections | X | | |
| Gas Fuel Piping | | | | |
| A. | Design Temperature at or below -18℃ | X | | |
| B. | Design Temperature above -18℃ and pressure10.3 bar or below | | X | |
| C. | Pressure above 10.3 bar | X | | |
| Valves, castings and forgings in gas fuel piping systems | | | | |
| A. | Design Temperature at or below -55℃ | X | | |
| B. | Design Temperature above -55℃ | | X | |

*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 of the Guidelines, and the weld* *properties shall be determined in the heat treated condition in accordance with 16.3 of the Guidelines. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Administration.*

## *16.2 General Test Regulations and Specifications*

*16.2.1 Tensile test*

*16.2.1.1 Tensile testing shall be carried out in accordance with recognized standards.*

*16.2.1.2 Tensile strength, yield stress and elongation shall be to the satisfaction of the Administration. For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.*

*16.2.2 Toughness test*

*16.2.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests unless otherwise specified by the Administration. The specified Charpy V-notch regulations are minimum average energy values for three full size (10mm × 10mm) 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* | *Minimum energy average of three specimens* |
|---|---|
| *10 × 10 mm* | $KV$ |
| *10 × 7.5 mm* | $\frac{5}{6}KV$ |
| *10 × 5.0 mm* | $\frac{2}{3}KV$ |

where:

*KV = the energy values (J) specified in tables 7-1 to 7-4 of the Guidelines.*

*Only one individual value may be below the specified average value, provided it is not less than 70% of that value.*

*16.2.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in Figure 16-1 .*

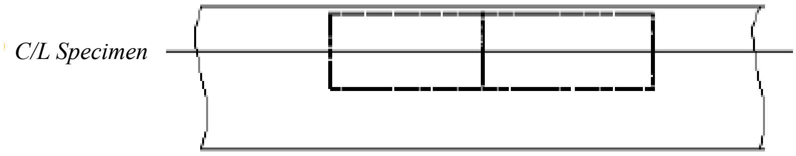



***Figure 16-1***
***Orientation of Base Metal Test Specimen***

*16.2.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases the distance from the surface of the material to the edge of the specimen shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the following locations, as shown in Figure 16-2, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.*

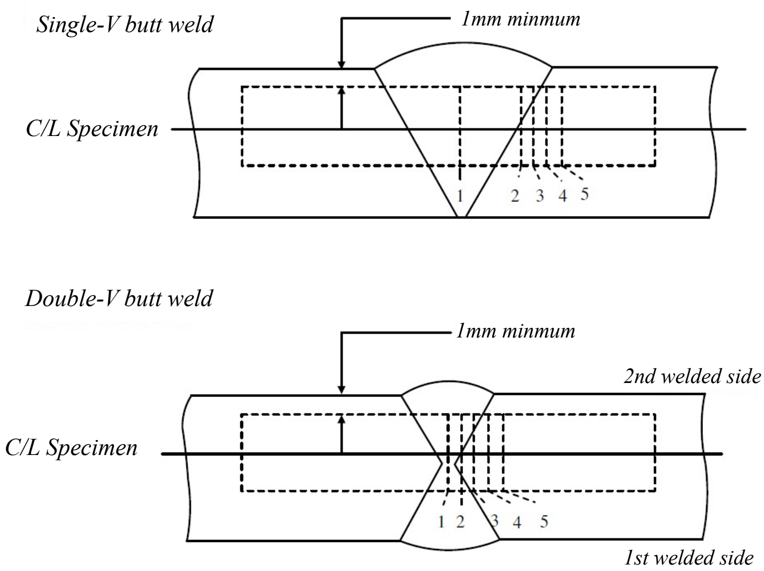



***Figure 16-2***
***Orientation of Weld Test Specimen***

*Notch locations in Figure 16-2:*

*.1 centreline of the weld;*

*.2 on fusion line;*

*.3 in heat-affected zone (HAZ), 1 mm from fusion line;*

*.4 in HAZ, 3 mm from fusion line; and*

*.5 in HAZ, 5 mm from fusion line.*

*16.2.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated regulations, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the regulations and if no more than two individual results are lower, than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.*

### *16.2.3 Bend test*

*16.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards.*

*16.2.3.2 The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Administration. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.*

*16.2.4 Section observation and other testing*

*Macrosection, microsection observations and hardness tests may also be required by the Administration, and they shall be carried out in accordance with recognized standards, where required.*

CR Interpretation of 16.2

(a) Definitions

(i) Piece

A piece is the rolled product from a single slab or billet or from a single ingot, if this is rolled directly into plates, strips, sections or bars.

(ii) Batch

A batch is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in the recognized standards.

(b) Test Samples

(i) All material in a batch presented for acceptance tests is to be of the same product form (e.g., plates, flats, sections, etc.) from the same cast and in the same condition of supply.

(ii) The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

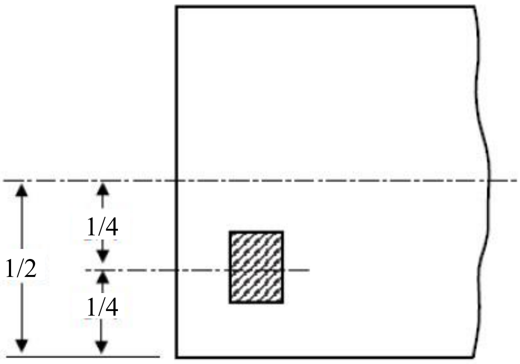
(iii) The test specimens are not to be separately heat treated in any way.

(iv) Unless otherwise agreed the test samples are to be taken from the following positions:

(1) Plates and Flats with a Width ≥ 600 mm.
The test samples are to be taken from one end at a position approximately midway between the axis in the direction of rolling and the edge of the rolled product (see Figure 16-3). Unless otherwise agreed the tension test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.

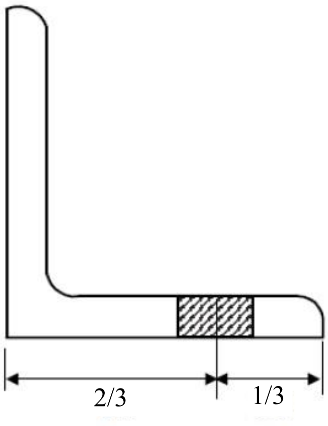
(2) Flats with a Width < 600 mm, Bulb Flats and Other Sections.
The test samples are to be taken from one end at a position approximately one-third from the outer edge (see Figure 16-4, Figure 16-5 and Figure 16-6) or in the case of small sections, as near as possible to this position. In the case of channels, beams or bulb angles, the test samples may alternatively be taken from a position approximately one quarter of the width from the web centerline or axis (see Figure 16-5). The tension test specimens may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling.

(3) Bars and Other Similar Products.
The test samples are to be taken so that the longitudinal axes of the test specimens are parallel to the direction of rolling.



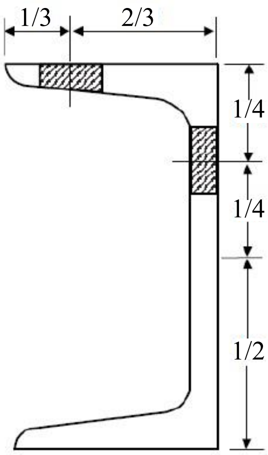

Plates and flats

**Figure 16-3**



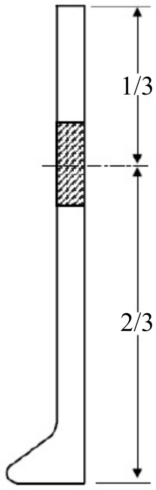

Angles

**Figure 16-4**




Channel and beams

**Figure 16-5**




Bulb flats

**Figure 16-6**

## *16.3 Welding of Metallic Materials and Non-Destructive Testing for The Fuel Containment System*

*16.3.1 General*

*This Chapter shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of the Administration, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.*

*16.3.2 Welding consumables*

*Consumables intended for welding of fuel tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information.*

*16.3.3 Welding procedure tests for fuel tanks and process pressure vessels*

*16.3.3.1 Welding procedure tests for fuel tanks and process pressure vessels are required for all butt welds.*

*16.3.3.2 The test assemblies shall be representative of:*

*.1 each base material;*

*.2 each type of consumable and welding process; and*

*.3 each welding position.*

*16.3.3.3 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.*

*16.3.3.4 The following welding procedure tests for fuel tanks and process pressure vessels shall be done in accordance with 16.2 of the Guidelines 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 of the Guidelines:*

*.1 centreline of the welds;*

*.2 fusion line;*

*.3 1 mm from the fusion line;*

*.4 3 mm from the fusion line; and*

*.5 5 mm from the fusion line;*

*.5 macrosection, microsection and hardness survey may also be required.*

*16.3.3.5 Each test shall satisfy the following:*

*.1 tensile tests: cross-weld tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. For aluminium alloys, reference shall be made to 6.4.12.1.1.3 of the Guidelines 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 of the Guidelines. 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 of the Guidelines. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards.*

*16.3.3.6 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.*

*16.3.4 Welding procedure tests for piping*

*Welding procedure tests for piping shall be carried out and shall be similar to those detailed for fuel tanks in 16.3.3 of the Guidelines.*

*16.3.5 Production weld tests*

*16.3.5.1 For all fuel tanks and process pressure vessels except membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Administration. Tests, other than those specified in 16.3.5.2 to 16.3.5.5 below may be required for fuel tanks or secondary barriers.*

*16.3.5.2 The production tests for types A and B independent tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the centre of the weld.*

*16.3.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 16.3.5.2 above. Tensile tests shall meet regulation 16.3.3.5 of the Guidelines.*

*16.3.5.4 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual (QM).*

*16.3.5.5 The test regulations for membrane tanks are the same as the applicable test regulations listed in 16.3.3 of the Guidelines.*

*16.3.6 Non-destructive testing*

*16.3.6.1 All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used in principle to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but in addition supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.*

*16.3.6.2 For type A independent tanks where the design temperature is below -20℃, 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 above.*

*16.3.6.3 In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods as considered necessary.*

*16.3.6.4 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:*

*.1 Total non-destructive testing referred to in 6.4.15.3.2.1.3 of the Guidelines*

*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 of the Guidelines, 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 of the Guidelines:*

*Radiographic testing:*

*.1 all butt welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed.*

*Non-destructive testing for surface crack detection:*

*.2 reinforcement rings around holes, nozzles, etc. over their full length.*

*Ultrasonic testing:*

*.3 as may be required by the Administration in each instance.*

*16.3.6.5 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM).*

*16.3.6.6 Inspection of piping shall be carried out in accordance with the regulations of chapter 7 of the Guidelines.*

*16.3.6.7 The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.*

## *16.4 Other Regulations for Construction in Metallic Materials*

*16.4.1 General*

*Inspection and non-destructive testing of welds shall be in accordance with regulations in 16.3.5 and 16.3.6 below. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.*

*16.4.2 Independent tank*

*For type C tanks and type B tanks primarily constructed of bodies of revolution the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in 6.4.15.2.3.1 and 6.4.15.3.3.2 of the Guidelines.*

*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 of the Guidelines).*

*16.4.4 Membrane tanks*

*The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.*

## *16.5 Testing*

*16.5.1 Testing and inspections during construction*

*16.5.1.1 All liquefied gas fuel tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 16.5.2 to 16.5.5 below, as applicable for the tank type.*

*16.5.1.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 16.5.1.1 above.*

*16.5.1.3 The gas tightness of the fuel containment system with reference to 6.3.3 of the Guidelines shall be tested.*

*16.5.1.4 Regulations with respect to inspection of secondary barriers shall be decided by the Administration in each case, taking into account the accessibility of the barrier (see also 6.4.4 of the Guidelines).*

*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 of the Guidelines 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 above. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.*

*16.5.1.6 The overall performance of the fuel containment system shall be verified for compliance with the design parameters during the first LNG bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements of the Administration. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained on board and be available to the Administration.*

*16.5.1.7 The fuel containment system shall be inspected for cold spots during or immediately following the first LNG bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with the requirements of the Administration.*

*16.5.1.8 Heating arrangements, if fitted in accordance with 6.4.13.1.1.3 and 6.4.13.1.1.4 of the Guidelines, shall be tested for required heat output and heat distribution.*

*16.5.2 Type A independent tanks*

*All type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.*

*16.5.3 Type B independent tanks*

*Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing as follows:*

*.1 The test shall be performed as required in 16.5.2 above for type A independent tanks.*

*.2 In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment.*

*16.5.4 Type C independent tanks and other pressure vessels*

*16.5.4.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 $P_0$. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield strength of the material at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.*

*16.5.4.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.*

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

*16.5.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 16.5.4.1 to 16.5.4.3 above.*

*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 above shall be fully complied with.*

*16.5.4.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in 16.5.4.1 or 16.5.4.4 above as applicable.*

*16.5.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks shall be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.*

*16.5.5 Membrane tanks*

*16.5.5.1 Design development testing*

*16.5.5.1.1 The design development testing required in 6.4.15.4.1.2 of the Guidelines 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 of the Guidelines may be based on the results of testing carried out on the prototype scaled model.*

*16.5.5.1.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.*

*16.5.5.2 Testing*

*.1 In ships fitted with membrane liquefied gas fuel containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.*

*.2 All hold structures supporting the membrane shall be tested for tightness before installation of the liquefied gas fuel containment system.*

.3 *Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.*

## *16.6 Welding, Post-Weld Heat Treatment and Non-Destructive Testing*

*16.6.1 General*

*Welding shall be carried out in accordance with 16.3 of the Guidelines.*

*16.6.2 Post-weld heat treatment*

*Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Administration may waive the regulations for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.*

*16.6.3 Non-destructive testing*

*In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the regulations in this paragraph, the following tests shall be required:*

.1 *100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with;*

  .1 *design temperatures colder than –10℃; 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 above, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.*

16.6.4 (CR) Type C Independent Tanks

16.6.4.1 For type C tanks of carbon and carbon-manganese steel, post-weld heat treatment shall be performed after welding, if the design temperature is below –10°C. Post-weld heat treatment in all other cases and for materials other than those mentioned above shall be to recognized standards. The soaking temperature and holding time shall be to the recognized standards.

16.6.4.2 In the case of type C tanks and large pressure vessels of carbon or carbon-manganese steel, for which it is difficult to perform the heat treatment, mechanical stress relieving by pressurizing may be carried out as an alternative to the heat treatment and subject to the following conditions:

.1 Complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates shall be heat treated before they are welded to larger parts of the pressure vessel;

.2 The mechanical stress relieving process shall preferably be carried out during the hydrostatic pressure test required by 16.5.4 of the Guidelines, by applying a higher pressure than the test pressure required by 16.5.4.1 of the Guidelines. The pressurizing medium shall be water;

.3 For the water temperature, 16.5.4.2 of the Guidelines applies;

.4 Stress relieving shall be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure;

.5 The maximum stress relieving pressure shall be held for 2 hr per 25 mm of thickness, but in no case less than 2 hr;

.6 The upper limits placed on the calculated stress levels during stress relieving shall be the following:

.1 Equivalent general primary membrane stress: $0.9R_e$;

.2 Equivalent stress composed of primary bending stress plus membrane stress: 1.35 $R_e$, where $R_e$ is the specific lower minimum yield stress or 0.2% proof stress at test temperature of the steel used for the tank;

.7 Strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges shall be included in the mechanical stress relieving procedure to be submitted in accordance with 16.6.4.2.14 below;

.8 The test procedure shall demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again upto the design pressure;

.9 High-stress areas in way of geometrical discontinuities such as nozzles and other openingsshall be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect shall be paid to plates exceeding 30 mm in thickness;

.10 Steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 shall generally not be mechanically stress relieved. If, however, the yield stress is raised by amethod giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case;

.11 Mechanical stress relieving cannot be substituted for heat treatment of cold formed parts of tanks, if the degree of cold forming exceeds the limit above which heat treatment is required;

.12 The thickness of the shell and heads of the tank shall not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved;

.13 Local buckling shall be guarded against, particularly when tori-spherical heads are used for tanks and domes; and

.14 The procedure for mechanical stress relieving is to be to a recognized standard.

## *16.7 Testing Regulations*

*16.7.1 Type testing of piping components*

Valves

*Each type of piping component intended to be used at a working temperature below –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℃, the type testing shall include a fire test to a standard at least equivalent to those acceptable to the Organization.*[(32)]

CR Interpretation of 16.7.1 Valves

.1 Prototype Testing

Each size and type of valve intended to be used at a working temperature below –55°C is to be approved through design assessment and prototype testing. Prototype testing for all valves, to the minimum design temperature or lower and to a pressure not lower than the maximum design pressure foreseen for the valves is to be witnessed in the presence of the Surveyor. Prototype testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure, and cryogenic testing consisting of valve operation at safety valve set pressure, and leakage verification. In addition, for valves other than safety valves, a seat and stem leakage test at a pressure equal to 1.1 times the design pressure.

For valves intended to be used at a working temperature above –55°C, prototype testing is not required.

.2 One of the following standards is to be used for the design assessment of the valves when required by 16.7.1.1 above, as applicable:

- ISO 21011 – Cryogenic vessels – Valves for cryogenic service
- ISO 21013 – Cryogenic vessels – Pressure-relief accessories for cryogenic service
- BS 6364 – Specification for Valves for cryogenic service
- EN 12567 – Industrial valves – Isolating valves for LNG – Specification for suitability and appropriate verification tests

Other applicable standards may be considered on a case by case basis.

.3 Unit Production Testing

All valves are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves, and seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below –55°C. The set pressure of safety valves is to be tested at ambient temperature. As an alternative to the above, the manufacturer may request CR to certify a valve subject to the following:

.1 The valve has been prototype tested as required by 16.7.1.1 of the Guidelines for valves intended to be used at a working temperature below –55°C, and

.2 The manufacturer has a recognized quality system that has been assessed and certified by CR subject to periodic audits, and

*Note 32:*

*Refer to the recommendations by the International Organization for Standardization, in particular publications:*

*ISO 19921:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods*

*ISO 19922:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench*

.3 The quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves and seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. The set pressure of safety valves is to be tested at ambient temperature. The manufacturer is to maintain records of such tests, and

.4 Cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below –55°C in the presence of the Surveyor.

*16.7.2 Expansion bellows*

*The following type tests shall be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable in 7.3.6.4.3.1.3 of the Guidelines and where required by the Administration, on those installed within the fuel tanks:*

*.1 Elements of the bellows, not pre-compressed, but axially restrained shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.*

*.2 A pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.*

*.3 A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.*

*.4 A cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.*

*16.7.3 System testing regulations*

*16.7.3.1 The regulations for testing in this Chapter apply to fuel piping inside and outside the fuel tanks. However, relaxation from these regulations for piping inside fuel tanks and open ended piping may be accepted by the Administration.*

*16.7.3.2 After assembly, all fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1.5 times the design pressure.*

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

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

*16.7.3.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, shall be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Administration.*

*16.7.3.6 Emergency shutdown valves in liquefied gas piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.*

*16.7.3.7 The closing time of the valve referred to in 8.5.8 and 15.4.2.2 of the Guidelines (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than:*

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

*where:*

$U$ = *ullage volume at operating signal level ($m^3$);*
$BR$ = *maximum bunkering rate agreed between ship and shore facility ($m^3/h$); or 5 seconds, whichever is the least.*

*The bunkering rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant.*

CR Interpretation of 16.7.3.7

The operating signal level mentioned in the definition of "$U$" in 16.7.3.7 above is the independent high liquid level ESD shutdown in relation to bunkering. "Ullage" is the volume above the liquid level of a partially filled fuel tank. The independent high liquid level ESD shutdown set point is to be at the loading limit determined in accordance with 6.8.1 of the Guidelines.

16.7.4 (CR) LNG Pumps

.1 Prototype Testing

Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Surveyor. In lieu of prototype testing, satisfactory in-service experience of an existing pump, design approved by the Society, may be considered when submitted by the manufacturer.

Prototype testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but must be of sufficient length to include at least one bearing and sealing arrangements. After completion of tests, the pump is to be opened out for examination.

.2 One of the following standards is to be used for the design assessment of the pumps, as applicable:

- ISO 13709 – Centrifugal pumps for petroleum, petrochemical and natural gas industries
- ISO 24490 – Cryogenic vessels – Pumps for cryogenic service

Other applicable standards may be considered on a case-by-case basis.

.3 Unit Production Testing

All pumps are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.

As an alternative to the above, if so requested by the relevant manufacturer, the certification of a pump may be issued subject to the following:

.1 The pump has been approved as required by 16.7.4.1 above, and

.2 The manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and

.3 The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

## 16.8 (CR) Surveys during Construction

16.8.1 General

This Chapter pertains to surveys during fabrication at the manufacturer's facility and installation and testing of fuel consumers, fuel tanks, reliquefaction systems, fuel supply systems, fuel bunkering systems and associated systems onboard the ship. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

16.8.2 Surveys at Manufacturer's Facility

Construction and testing of equipment and systems referenced by 16.8.1 above and components thereof is to be in accordance with the applicable requirements of the Rules for Steel Ships.

Certification of complete equipment and systems cannot be accepted based only on the Guidelines for Survey of Products for Marine Use, and therefore the Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with the CR Guidelines for Survey of Products for Marine Use.

When the Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules, the manufactured/assembled system components will be verified to be satisfactorily in compliance with the aforementioned Rules. The Surveyor's attendance is required typically for the following purposes:

.1 To confirm that the facility to manufacture, fabricate or repair equipment or systems referenced by 16.8.1 above or their components does have and maintain a quality control program effectively covering design, procurement, manufacturing and testing, asapplicable, and meeting the requirements of a recognized standard applicable to their product.

.2 To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

.3 To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded endsor other specialty fittings. Witness of material testing where required by the Rules for Steel Ships.

.4 To survey final weldments.

.5 To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of non-destructive examinations.

.6 To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

.7 To witness testing of subassemblies and completed units as called for in the fabrication procedures.

.8 To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

.9 To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

16.8.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the equipment or system during installation and testing, as applicable:

.1 Piping systems are to be visually examined and pressure-tested, as required by 16.7.4 of the Guidelines.

.2 Electrical wiring and connections are to be in accordance with Part VII of the Rules for Steel Ships and Chapter 14 of the Guidelines as applicable and checked for continuity and proper workmanship.

.3 Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

.4 Pressure relief and safety valves are to be tested.

.5 Control system and shutdowns are to be tested for proper operation.

.6 The equipment or systems operation is to be checked for proper operation.

.7 Availability of operation manuals onboard to be verified.

16.8.4 Surveys During Trials

During the initial gas trials, the equipment and systems are to be confirmed for satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the testing procedure during gas trials.

**Table 16-1**
**(CR) Certification of Fuel Tanks and Fuel Storage Hold Space**

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment (1) | DR | MT | MS | FS |
|---|---|---|---|---|
| LNG/CNG tanks | X | X | X | X |
| LNG pumps | X | | | X |
| Tank valves, pressure relief valves and associated piping | X | X | X | X |
| Fuel gas piping system in tank connection space and fuel storage hold space, as applicable | X | X | X | X |
| Ventilation system and fire dampers in tank connection space | X | | | X |
| Hold space inert gas system | X | | | X |
| Tank monitoring system | X | | | X |
| Fire detection system | X | | | X |
| Gas detection system | X | | | X |

Note:

(1) See 6.4.15.3.1.

## Table 16-2
## (CR) Certification of Reliquefaction Systems

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer’s facility or during installation and trials onboard, as applicable. |

| Equipment | DR | MT | MS | FS |
|---|---|---|---|---|
| BOG compressors | X | | | X |
| LNG pumps | X | | | X |
| Pump and compressor motors (rated at 75 kW and over) | X | | | X |
| LNG separators | X | X | | X |
| Refrigerant compressors/expanders | X | | | X |
| Cryogenic heat exchanger/cold box (1) | X | X | X | X |
| Refrigerant/Sea water coolers (1) | X | | X | X |
| Refrigerant accumulators (1) | X | | X | X |
| Reliquefaction control system | X | | | X |
| Gas detection system | X | | | X |
| Automatic shutdown and safety system | X | | | X |

Note:
(1) See 6.4.15.3.1.

**Table 16-3**
**(CR) Certification of GCU**

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| MD | Manufacturer's Documentation – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.). |
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment | MD | DR | MT | MS | FS |
|---|---|---|---|---|---|
| Gas burner unit including oil pilot burner | X | | | | |
| Burner management system | | X | | | X |
| Combustion chamber and associated refractory | X | | | | |
| Forced draft fans and dilution fans | X | | | | |
| Exhaust trunk | X | | | | |
| Combustion chamber cooling water pumps | X | | | | X |
| Gas detection system | | X | | | X |
| Automatic shutdown and safety system | | X | | | X |

**Table 16-4**
**(CR) Certification of Bunkering Systems**

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
| --- | --- |
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment | DR | MT | MS | FS |
| --- | --- | --- | --- | --- |
| Bunker manifolds | X | X | X | X |
| Manifold valves, ESD valves and associated piping | X | X | X | X |
| Bunker piping system | X | X | X | X |
| Bunker piping ventilation system where fitted | X | | | |
| Monitoring system | X | | | X |
| Fire detection system | X | | | X |
| Fire extinguishing system | X | | | X |
| Gas detection system (1) | X | | | X |
| Automatic shutdown and safety system | X | | | X |

Note:
(1) See 8.6.

**Table 16-5**
**(CR) Certification of Fuel Gas Supply Systems**

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment | DR | MT | MS | FS |
|---|---|---|---|---|
| BOG compressors | X | | | X |
| LNG pumps | X | | | X |
| Pump and compressor motors (rated at 75 kW and over) | X | | | X |
| Pressure vessels and heat exchangers (1) | X | X (2) | X | X |
| LNG piping with design temperature at or below –18°C or design pressure above 10.3 bar | X | X (3) | | X |
| LNG piping with design temperature above –18°C and design pressure of 10.3 bar or less | X | | | |
| Cryogenic valves with design temperature at or below –55°C | X | X | X | X |
| Valves with design temperature above –18°C | X | | | X |
| Fuel gas supply piping with design temperature at or below –18°C or design pressure above 10.3 bar | X | X | | X |
| Fuel gas supply piping with design temperature above –18°C and design pressure of 10.3 bar or less | X | | | |
| Fuel gas piping ventilation system | X | | | X |
| Fuel preparation room ventilation system | X | | | X |
| Control and monitoring system | X | | | X |
| Fire detection system | X | | | X |
| Fire extinguishing system | X | | | X |
| Gas detection systems | X | | | X |
| Automatic shutdown and safety system | X | | | X |

Notes:

(1) see 6.4.15.3.1.

(2) Requirement for witnessed material testing will depend on process and design conditions, see 16.1.1.1.

(3) For open-ended vent piping referenced by 9.5.2 of the Guidelines, the Surveyor witnessed materials tests are only required for minimum design temperatures below –55°C.

**Table 16-6**
**(CR) Certification Guidance for Fuel Gas Supply System Components**

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Component | Validity | Design Assessment | Prototype Testing | Production Testing | Materials Testing |
|---|---|---|---|---|---|
| Valves, (other than safety valves) | <-55°C | Required | Each type and size of valve: W, H (valve body), CO, SS | Each valve: W, H (valve body), SS, CO(at least 10% of each type and size of valve) (1) | W |
| | >-55°C | Not required 16.7.1.1 | Not required | Each valve: W, H (valve body), SS (1) | |
| Safety valves | <-55°C | Required 16.7.1.1 | Each type and size of valve: W, H (valve body), CO | Each valve: W, H (valve body), RV (1) | W |
| | >-55°C | Not required 16.7.1.1 | Not required | Each valve: W, H (valve body), RV (1) | |
| LNG pumps | All | Required 9.11.3 | Each type and size of pump: W, H (pump body), PC, ST,IE (2) | Each pump: W, H, PC(3) | |
| Expansion bellows (metallic type) | All | Required 4.10.8 of Part X of the Rules for Steel Ships | Each type of bellows:H5, H2, CT, CF | Each bellows: H [as part of general piping system pressure testing after installation to 1.5P, but not less than 4 bar] | |

| Key: | | |
|---|---|---|
| | W | Witnessed by the Surveyor |
| | H | Hydrostatic pressure test at 1.5 times the design pressure |
| | CO | Cryogenic operation and leakage test at design pressure and minimum design temperature |
| | SS | Seat and stem leakage test at 1.1 times the design pressure |
| | RV | Set pressure of safety valves to be tested at ambient temperature |
| | PC | Pump capacity test as per 16.7.4.1 or 16.7.4.3, as applicable |
| | H5 | Pressure test of bellows element at 5 times the design pressure for not less than 5 minutes as per 16.7.2.1 of the Guidelines |
| | H2 | Pressure test of complete bellows assembly at 2 times the design pressure as per 16.7.2.2 |
| | CT | Cyclic test as per 16.7.2.3 |
| | CF | Cyclic fatigue test as per 16.7.2.4 |
| | ST | Spin test for shaft driven deep well pumps as per 16.7.4.1 |
| | IE | Dismantling and internal examination of pump after completion of prototype testing as per 16.7.4.1 |

Notes:

(1) Alternative certification route is possible as per 16.7.1 of the Guidelines.
(2) Alternative to prototype testing may be accepted as per 16.7.4.1 of the Guidelines.
(3) Alternative to production testing may be accepted as per 16.7.4.3 of the Guidelines.

## Table 16-7
## (CR) Certification of Engines

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment | DR | MT | MS | FS |
|---|---|---|---|---|
| Gas valve unit/gas valve train enclosure | X | | | X |
| Crankcase, inlet manifold and exhaust manifold explosion protection systems | X | | | X |
| Control system | X | | | X |
| Automatic shutdown and safety systems | X | | | X |

## Table 16-8
## (CR) Certification of Dual Fuel Gas Turbines

This table has been prepared and annotated to agree with the Guidelines, IMO IGF Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the Rules for Steel Ships, the IGF Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the Rules for Steel Ships and/or other applicable Regulations.

| Code | Explanation |
|---|---|
| DR | Design Review – Design review required. |
| MT | Material Testing – Material testing is to be witnessed by the Surveyor. |
| MS | Manufacture Survey – Product is to be surveyed during fabrication stages by the Surveyor. |
| FS | Final Survey – Finished product is to be subject to final hydrostatic, non-destructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility or during installation and trials onboard, as applicable. |

| Equipment | DR | MT | MS | FS |
|---|---|---|---|---|
| Dual fuel gas turbine enclosure | X | | | X |
| Gas fuel manifold | X | X | | X |
| Dual fuel gas turbine enclosure ventilation system | X | | | |
| Dual fuel gas turbine enclosure firefighting system | X | | | |
| Dual fuel gas turbine combustion air supply ducting | X | | | |
| Dual fuel gas turbine exhaust system | X | | | |
| Gas detection system for dual fuel gas turbine enclosure | X | | | X |
| Dual fuel gas turbine combustion control system | X | | | X |
| Automatic shutdown and safety system | X | | | X |

# *CHAPTER 17 DRILLS AND EMERGENCY EXERCISES*

Note:
The IGF Code PART C-1 is incorporated into Chapters 17 to 18 of the Guidelines.

***PART C-1***

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

*Drills and emergency exercises on board shall be conducted at regular intervals.*

*Such gas-related exercises could include for example:*

*.1 tabletop exercise;*

*.2 review of fueling procedures based in the fuel handling manual required by 18.2.3 of the Guidelines;*

*.3 responses to potential contingences;*

*.4 tests of equipment intended for contingency response; and*

*.5 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.*

*Gas related exercises may be incorporated into periodical drills required by SOLAS.*

*The response and safety system for hazards and accident control shall be reviewed and tested.*

# *CHAPTER 18 OPERATION*

## *18.1 Goal*

*The goal of this chapter is to ensure that operational procedures for the loading, storage, operation, maintenance, and inspection of systems for gas or low-flashpoint fuels minimize the risk to personnel, the ship and the environment and that are consistent with practices for a conventional oil fuelled ship whilst taking into account the nature of the liquid or gaseous fuel.*

## *18.2 Functional Requirements*

*This chapter relates to the functional requirements in 3.2.1 to 3.2.3, 3.2.9, 3.2.11, 3.2.15, 3.2.16 and 3.2.17 of the Guidelines. In particular the following apply:*

*.1 a copy of the IGF Code, or national regulations incorporating the provisions of the IGF Code, shall be on board every ship covered by the IGF Code;*

*.2 maintenance procedures and information for all gas related installations shall be available on board;*

*.3 the ship shall be provided with operational procedures including a suitably detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems; and*

*.4 the ship shall be provided with suitable emergency procedures.*

## *18.3 Regulations for Maintenance*

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

*18.3.2 In-service survey, maintenance and testing of the fuel containment system are to be carried out in accordance with the inspection/survey plan required by 6.4.1.8 of the Guidelines.*

*18.3.3 The procedures and information shall include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces shall be performed in accordance with a recognized standard.[(33)]*

*Note 33:*
*Refer to IEC 60079 17:2007 Explosive atmospheres – part 17: Electrical installations inspection and maintenance.*

18.3.4 (CR) Operating and Maintenance Instruction Manuals

The manuals are to include, but not be limited to, the regular test and maintenance procedures for the gas detection systems, safety shut-off systems and the integrity of backup systems together with details of required personal protective equipment and the occupational health hazards relevant to the use of gas as a fuel. The maintenance procedures are to specify who is qualified to carry out maintenance.

Operating and maintenance manuals are to be submitted for reference purposes only.

## *18.4 Regulations for Bunkering Operations*

*18.4.1 Responsibilities*

*18.4.1.1 Before any bunkering operation commences, the master of the receiving ship or his representative and the representative of the bunkering source (Persons In Charge, PIC) shall:*

*.1 agree in writing the transfer procedure, including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred;*

*.2 agree in writing action to be taken in an emergency; and*

*.3 complete and sign the bunker safety check-list.*

*18.4.1.2 Upon completion of bunkering operations the ship PIC shall receive and sign a Bunker Delivery Note for the fuel delivered, containing at least the information specified in the Annex 4, completed and signed by the bunkering source PIC.*

*18.4.2 Overview of control, automation and safety systems*

*18.4.2.1 The fuel handling manual required by 18.2.3 of the Guidelines 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;*

CR Interpretation of 18.4.2.1.7

the gas detection systems and associated emergency shutdown systems are to be tested and maintained to verify their reliability in accordance with 2.10 of Part I of the Rules for Steel Ships.

*.8 emergency shutdown and emergency release systems, where fitted; and*

*.9 a description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover.*

.10 (CR)

emergency ship-to-ship transfer procedure, if applicable.

.11 (CR)

procedures to ensure the fuel gas supplied is in accordance with the engine manufacturer's specifications detailed under 10.3.1.8 of the Guidelines.

.12 (CR)

any limitation to personnel engaged in bunkering operation.

.13 (CR)

identification of appropriate personal protective equipment.

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

*18.4.3 Pre-bunkering verification*

*18.4.3.1 Prior to conducting bunkering operations, pre-bunkering verification including, but not limited to the following, shall be carried out and documented in the bunker safety checklist:*

*.1 all communications methods, including ship shore link (SSL), if fitted;*

*.2 operation of fixed gas and fire detection equipment;*

*.3 operation of portable gas detection equipment;*

*.4 operation of remote controlled valves; and*

*.5 inspection of hoses and couplings.*

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

*18.4.4 Ship bunkering source communications*

*18.4.4.1 Communications shall be maintained between the ship PIC and the bunkering source PIC at all times during the bunkering operation. In the event that communications cannot be maintained, bunkering shall stop and not resume until communications are restored.*

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

*18.4.4.3 PIC's shall have direct and immediate communication with all personnel involved in the bunkering operation.*

*18.4.4.4 The ship shore link (SSL) or equivalent means to a bunkering source provided for automatic ESD communications, shall be compatible with the receiving ship and the delivering facility ESD system.(34)*

*18.4.5 Electrical bonding*

*Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering shall be electrically continuous, suitably insulated and shall provide a level of safety compliant with recognized standards.(35)*

*Note 34: Refer to ISO 28460, ship-shore interface and port operations.*

*Note 35:Refer to API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals.*

CR Interpretation of 18.4.5

Where required by local regulations, an equipotential bonding connection is to be made between the bunker supplier and the receiving ship. The bonding connection is to be located away from the manifold in a non-hazardous area.

*18.4.6 Conditions for transfer*

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

*18.4.6.2 During the transfer operation, personnel in the bunkering manifold area shall be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations shall wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer shall be cause to stop operations and transfer shall not be resumed until all required conditions are met.*

*18.4.6.3 Where bunkering is to take place via the installation of portable tanks, the procedure shall provide an equivalent level of safety as integrated fuel tanks and systems. Portable tanks shall be filled prior to loading on board the ship and shall be properly secured prior to connection to the fuel system.*

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

18.4.6.5 (CR)

Manifold connections not being used for bunker transfer operations are to be blanked with blind flanges rated for the design pressure of the pipeline system.

## *18.5 Regulations for Enclosed Space Entry*

*18.5.1 Under normal operational circumstances, personnel shall not enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of an explosive atmosphere.*[(36)]

*18.5.2 Personnel entering any space designated as a hazardous area shall not introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.*

## *18.6 Regulations for Inerting and Purging of Fuel Systems*

*18.6.1 The primary objective in inerting and purging of fuel systems is to prevent the formation of a combustible atmosphere in, near or around fuel system piping, tanks, equipment and adjacent spaces.*

*Note 36:*

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

*18.6.2 Procedures for inerting and purging of fuel systems shall ensure that air is not introduced into piping or a tank containing gas atmospheres, and that gas is not introduced into air contained in enclosures or spaces adjacent to fuel systems.*

## *18.7 Regulations for Hot Work on or near Fuel Systems*

*18.7.1 Hot work in the vicinity of fuel tanks, fuel piping and insulation systems that may be flammable, contaminated with hydrocarbons, or that may give off toxic fumes as a product of combustion shall only be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained.*

# *CHAPTER 19 TRAINING*

*Note:*
*The IGF Code PART D is incorporated into Chapter 19 of the Guidelines.*

***PART D***

## *19.1 Goal*

*The goal of this chapter is to ensure that seafarers on board ships to which the IGF Code applies are adequately qualified, trained and experienced.*

## *19.2 Functional Requirements*

*Companies shall ensure that seafarers on board ships using gases or other low-flashpoint fuels shall have completed training to attain the abilities that are appropriate to the capacity to be filled and duties and responsibilities to be taken up, taking into account the provisions given in the STCW Convention and Code, as amended.*