

# **RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS**

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

**Part GF**

**Ships Using Low-Flashpoint Fuels**

**Rules for the Survey and Construction of Steel Ships**

**Part GF**

**ESTABLISHMENT**

**Guidance for the Survey and Construction of Steel Ships**

**Part GF**

**ESTABLISHMENT**

Rule No.82 / Notice No.83      27th December 2016

Resolved by Technical Committee on 27th July 2016

Approved by Board of Directors on 20th September 2016

**ClassNK**  
NIPPON KAIJI KYOKAI

An asterisk (\*) after the title of a requirement indicates that there is also relevant information in the corresponding Guidance.

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# **RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS**

**Part GF**

**Ships Using Low-Flashpoint Fuels**

**RULES**

## **2016 ESTABLISHMENT**

Rule No.82      27th December 2016

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AMENDMENT TO THE RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

“Rules for the survey and construction of steel ships” has been partly amended as follows:

Part GF has been established as follows.

## **Part GF      SHIPS USING LOW-FLASHPOINT FUELS**

### **Chapter 1      GENERAL**

#### **1.1      General (*IGF Code 2.1*)**

##### **1.1.1      Application**

**1** This Part is to apply to ships using low-flashpoint fuels, however, does not apply to the ships specified in the following **(1)** or **(2)**:

- (1) Gas carriers using their cargoes as fuel and complying with the requirements of **Part N**; or
- (2) Gas carriers using other low-flashpoint gaseous fuels provided that the fuel storage and distribution systems design and arrangements for such gaseous fuels comply with the requirements of **Part N**.

**2** Notwithstanding the requirement specified in **-1** above, for the ships specified in the following **(1)** or **(2)**, some requirements of this Part may be modified, as appropriate.

- (1) ships to which *SOLAS* Chapter II-1 does not apply; or
- (2) ships owned or operated by the flag State and used, for the time being, only in its non-commercial service.

**3** In the case of ships that using low-flashpoint fuels other than natural gas, **Chapters 5 to 15** of this Part do not apply. In the meantime, for other low-flashpoint fuels, compliance with the functional requirements of this Part must be demonstrated through alternative design.

##### **1.1.2      Equivalency**

The construction, equipment, etc. which do not fall under the provisions of this Part may be accepted provided that they are considered equivalent to those required in this Part in accordance with *SOLAS* regulation II-1/55.

##### **1.1.3      Approval of Systems and Equipment, etc.\***

**1** For ships using natural gas as fuel, the systems and equipment following **(1)** to **(20)** that are provided to use the gas fuel are to be approved as specified separately by the Society.

- (1) Fuel vapour compressors
- (2) Fuel pumps
- (3) Heat exchangers used for the heating, evaporation or cooling of fuel
- (4) Valves used for fuel containment systems, process pressure vessels, fuel piping and process piping
- (5) Relief valves (including vacuum relief valves) used for fuel containment systems, process pressure vessels, fuel piping and process piping
- (6) Bellows and expansion joints used for fuel piping and process piping systems (**16.7.2**)
- (7) Inert gas generator systems, including nitrogen generator systems, inert gas storage systems and

liquid nitrogen tanks

- (8) Systems for measuring fuel liquid levels in fuel containment systems and process pressure vessels, and liquid levels in nitrogen tanks
- (9) Systems for measuring fuel liquid or vapour pressures or atmospheric pressures in fuel containment systems and process pressure vessels
- (10) Devices for measuring and indicating the temperatures of the fuel liquids or vapours in fuel containment systems and process pressure vessels (**6.9**, **15.3** and **15.4**)
- (11) Insulation materials used in fuel containment systems and applied to fuel piping (**6.4.8** and **7.3.1-4**)
- (12) Fixed-type and portable-type oxygen content measuring equipment used in the inert atmosphere
- (13) Systems for measuring humidity of dry inert gas (**6.3.1-12**, **6.11.1** and **6.12.1**)
- (14) Water spray systems (**11.5**)
- (15) Dry chemical fire-extinguishing equipment (**11.6**)
- (16) Mechanical ventilation systems serving spaces containing gas sources (**13.3.3**)
- (17) Fuel hoses (**6.5.5** and **8.3.2**)
- (18) Removable liquefaction pumps, heat exchangers and associated piping systems (hereinafter referred to as “removable equipment”) which are temporarily placed or installed on board ships using low-flashpoint fuels for operations of a specific purpose.
- (19) Gas-fuelled boilers
- (20) Gas-fuelled engines

**2** For ships that use low-flashpoint fuels other than natural gas, systems and equipment specified in **-1(1)** to **(20)** above provided for the purpose of using the low-flashpoint fuels are to be those deemed appropriate by the Society.

**3** Boilers and internal combustion engines of piston type that are multi-fuel engines, and gas turbines are to be those deemed appropriate by the Society.

## **1.2 Alternative Design (*IGF Code 2.3*)**

### **1.2.1 General**

**1** This Part contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels.

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

- (1) deviate from those set out in this Part, or
- (2) be designed for use of a fuel not specifically addressed in this Part.

**3** The equivalence of the alternative design is to be demonstrated as specified in **1.1.2** and approved by the Society and Administration. However, operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Part are not acceptable.

## Chapter 2 DEFINITIONS

### 2.1 General

#### 2.1.1 Application

Unless expressly provided otherwise, terms used in this Part are defined as follows:

### 2.2 Definitions (*IGF Code 2.2*)

#### 2.2.1 Terms\*

**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** *Breadth (B')* means the greatest moulded breadth of the ship at or below the deepest subdivision draught (summer load line draught) (refer to **4.1.2(3), Part C**).

**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.

**4** *Certified safe type* means electrical equipment deemed appropriate by the Society for operation in a flammable atmosphere.

**5** *CNG* means compressed natural gas (see also **2.2.1-26**).

**6** *Control station* means those spaces defined in **3.2.18, Part R** and additionally for this Part, the engine control room.

**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.

**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.

**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.

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

**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.

**12** *ESD* means emergency shutdown.

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

**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.

**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 following **(1)** to **(3)**:

**(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.
- 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.
- 17 *Fuel preparation room* means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.
- 18 *Gas* means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C.
- 19 *Gas consumer* means any unit within the ship using gas as a fuel.
- 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.
- 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.
- 22 *High pressure* means a maximum working pressure greater than 1.0 MPa.
- 23 *Independent tanks* are self-supporting, do not form part of the ship's hull and are not essential to the hull strength.
- 24 *LEL* means the lower explosive limit.
- 25 *Length (L<sub>p</sub>)* is the length as defined in **2.1.3, Part A**.
- 26 *LNG* means liquefied natural gas.
- 27 *Loading limit (LL)* means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.
- 28 *Low-flashpoint fuel* means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under **4.2.1(1), Part R**.
- 29 *MARVS* means the maximum allowable relief valve setting.
- 30 *MAWP* means the maximum allowable working pressure of a system component or tank.
- 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.
- 32 *Multi-fuel engines* means engines that can use two or more different fuels that are separate from each other.
- 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.
- 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.
- 35 *Risk* is an expression for the combination of the likelihood and the severity of the consequences.
- 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).
- 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.
- 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.
- 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.
- 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 **1.3.1-4, Part D**.

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

**42** *Fuel* is defined as follows:

- (1) In applying to **Chapters 5 to 15** of this Part, *fuel* means natural gas, either in its liquefied or gaseous state. It is to be recognized that the composition of natural gas may vary depending on the source of natural gas and the processing of the gas.
- (2) In applying to **Chapters 16 and 17** of this Part, *fuel* means natural gas, either in its liquefied or gaseous state.

**43** *IGF Code* means the International Code of safety for ships using gases or other low-flashpoint fuels as adopted by the Maritime Safety Committee of the Organization of the International Maritime Organization (hereinafter referred to as “*IMO*”) by resolution *MSC.391(95)*, as may be amended by the *IMO*, provided that such amendments are adopted, brought into force and take effect in accordance with the provisions of article VIII of the present *SOLAS* concerning the amendment procedures applicable to the annex other than chapter I thereof.

## **Chapter 3      GOAL AND FUNCTIONAL REQUIREMENTS**

### **3.1      Goal (*IGF Code 3.1*)**

#### **3.1.1      General**

The goal of this Part 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 (*IGF Code 3.2*)**

#### **3.2.1      Safety, Reliability and Dependability of the Systems**

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

#### **3.2.2      Fuel-related Hazards**

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

#### **3.2.3      Design of Gas Fuel Installations**

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

#### **3.2.4      Minimization of Hazardous Areas**

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

#### **3.2.5      Equipment Installed in Hazardous Areas**

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

#### **3.2.6      Accumulation of Gas**

Unintended accumulation of explosive, flammable or toxic gas concentrations is to part be prevented.

#### **3.2.7      Protection of System Components**

System components are to be protected against external damages.

#### **3.2.8      Sources of Ignition in Hazardous Areas**

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

#### **3.2.9      Gas Fuel Supply, Storage and Bunkering Arrangements**

It is to be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when

necessary for safety reasons, the system is to be designed to prevent venting under all normal operating conditions including idle periods.

#### **3.2.10 Fitting for Intended Application**

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

#### **3.2.11 Machinery, Systems and Components**

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

#### **3.2.12 Arrangements and Locations of Machinery Spaces**

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

#### **3.2.13 Safety and Reliability for Operation**

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

#### **3.2.14 Arrangement of Fixed Gas Detection**

Fixed gas detection suitable for all spaces and areas concerned is to be arranged.

#### **3.2.15 Fire Detection, Protection and Measures**

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

#### **3.2.16 Confirmation of Fuel Systems and Gas Utilization Machinery**

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

#### **3.2.17 Assessment of Compatibility**

The technical documentation is to 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 Reliability of Systems or Components**

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

## **Chapter 4      GENERAL REQUIREMENTS**

### **4.1      Goal (*IGF Code 4.1*)**

#### **4.1.1      General**

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 (*IGF Code 4.2*)**

#### **4.2.1      General Requirements**

A risk assessment is to 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 is to be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

#### **4.2.2      Scope of Risk Assessment**

For ships to which **Chapters 5 to 15** of this Part applies, the risk assessment required by **4.2.1** need only be conducted where explicitly required by **5.10.5, 5.12.3, 6.4.1-1, 6.4.15-4(7)(b), 8.3.1-1, 13.4.1, 13.7 and 15.8.1(10)** as well as by **4-4. and 6-8. of Annex 6.4.16**.

#### **4.2.3      Analysis and Mitigation of Risk**

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

### **4.3      Limitation of Explosion Consequences (*IGF Code 4.3*)**

#### **4.3.1      General Requirements\***

An explosion in any space containing any potential sources of release and potential ignition sources are not to:

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

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

## **Chapter 5      SHIP DESIGN AND ARRANGEMENT**

### **5.1      Goal (*IGF Code 5.1*)**

#### **5.1.1      General**

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

### **5.2      Functional Requirements (*IGF Code 5.2*)**

#### **5.2.1      General**

This chapter is related to functional requirements in 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In addition, 5.2.2 applies.

#### **5.2.2      Additional Requirements**

- 1** The fuel tank(s) is to be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship.
- 2** Fuel containment systems, fuel piping and other fuel sources of release are to be so located and arranged that released gas is lead to a safe location in the open air.
- 3** The access or other openings to spaces containing fuel sources of release are to be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases.
- 4** Fuel piping is to be protected against mechanical damage.
- 5** The propulsion and fuel supply system are to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power.
- 6** The probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery is to be minimized.

### **5.3      General Requirements (*IGF Code 5.3*)**

#### **5.3.1      Fuel Tank Protection**

Fuel storage tanks are to be protected against mechanical damage.

#### **5.3.2      Fuel Tank Ventilation**

Fuel storage tanks and equipment located on open decks are to be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

#### **5.3.3      Fuel Tank Location**

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

- (1) The fuel tanks are to be located at a minimum distance of  $B/5$  or  $11.5m$ , whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught.
- (2) The boundaries of each fuel tank are to be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

- (3) For independent tanks the protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance is to be measured to the bulkheads surrounding the tank insulation.
- (4) In no case is the boundary of the fuel tank to be located closer to the shell plating or aft terminal of the ship than as follows:
  - i) for  $V_c$  below or equal  $1,000m^3$ ,  $0.8m$ ;
  - ii) for  $1,000m^3 < V_c < 5,000m^3$ ,  $0.75 + V_c \times 0.2 / 4,000 m$ ;
  - iii) for  $5,000m^3 \leq V_c < 30,000m^3$ ,  $0.8 + V_c / 25,000 m$ ; and
  - iv) for  $V_c \geq 30,000m^3$ ,  $2m$ ,
 where:  
 $V_c$  corresponds to 100% of the gross design volume of the individual fuel tank at  $20^\circ C$ , including domes and appendages.
- (5) The lowermost boundary of the fuel tank(s) is to be located above the minimum distance of  $B'/15$  or  $2.0m$ , 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) are to be abaft the collision bulkhead.
- (8) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 1.2.

#### 5.3.4 Alternative Fuel Tank Locations

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 is to be less than 0.04. The value  $f_{CN}$  accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.
- (2) The  $f_{CN}$  is calculated by the following formulation:

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

where:

$f_l$ : calculated by use of the formulations for factor  $p$  contained in 4.2.2-2, **Part C of the Rules**.  
 The value of  $x_1$  is to correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of  $x_2$  is to correspond to the distance from the aft terminal to the foremost boundary of the fuel tank.

$f_t$ : calculated by use of the formulations for factor  $r$  contained in 4.2.2-3, **Part C of the Rules**, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is follows. When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline the value of  $b$  is to be taken as 0.

$$f_t = 1 - r(x_1, x_2, b)$$

$f_v$ : calculated by following formulation:

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

$$f_v = 0.2 - 0.2 \cdot ((H - d) - 7.8) / 4.7, \text{ in all other cases } f_v \text{ is not to be taken less than } 0.$$

where:

$H$ : the distance from baseline, in metres, to the lowermost boundary of the fuel tank

$d$ : the deepest draught (summer load line draught)

- (3) The boundaries of each fuel tank are to be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.
- (4) For independent tanks the protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance is to be measured to the bulkheads surrounding the tank insulation.
- (5) In no case is the boundary of the fuel tank to be located closer to the shell plating or aft terminal of the ship than as follows:
  - i) for  $V_c$  below or equal  $1,000m^3$ ,  $0.8m$ ;
  - ii) for  $1,000m^3 < V_c < 5,000m^3$ ,  $0.75 + V_c \times 0.2 / 4,000 m$ ;
  - iii) for  $5,000m^3 \leq V_c < 30,000m^3$ ,  $0.8 + V_c / 25,000 m$ ; and
  - iv) for  $V_c \geq 30,000m^3$ ,  $2m$ ,
 where:  
 $V_c$  corresponds to 100% of the gross design volume of the individual fuel tank at  $20^\circ C$ , including domes and appendages.
- (6) In case of more than one non-overlapping fuel tank located in the longitudinal direction,  $f_{CN}$  is to be calculated in accordance with (2) for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for  $f_{CN}$  obtained for each separate tank.
- (7) In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of  $f_{CN}$  is to be calculated on both starboard and port side and the average value is to be used for the assessment. The minimum distance as set forth in (5) is to be met on both sides.
- (8) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 1.2.

### 5.3.5 Protection for Fuel Storage Hold Spaces

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

- (1) fuel storage hold spaces are to be segregated from the sea by a double bottom; and
- (2) the ship is also to have a longitudinal bulkhead forming side tanks.

## 5.4 Machinery Space Concepts (IGF Code 5.4)

### 5.4.1 General

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 following (1) or (2):

- (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 is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type. In an ESD protected machinery space a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures. Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements.



## **5.5 Gas Safe Machinery Space (*IGF Code 5.5*)**

### **5.5.1 Prevention of the Release of Gas**

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

### **5.5.2 Fuel Piping**

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

## **5.6 ESD-protected Machinery Spaces (*IGF Code 5.6*)**

### **5.6.1 Application**

*ESD* protection is to be limited to machinery spaces where monitoring and control systems for periodically unattended machinery spaces are installed in accordance with **the Rules for Automatic and Remote Control Systems**.

### **5.6.2 Protectional Measures**

Measures are to be applied to protect against explosion, damage of areas outside of the machinery space and ensure redundancy of power supply. The arrangement following (1) to (4) is to 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**

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

- (1) Engines for generating propulsion power and electric power are to be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces.
- (2) The gas machinery space is to 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, is to be fitted.

### **5.6.4 Distribution of Engines**

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

### **5.6.5 Strength of Spaces**

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

### **5.6.6 Shape of Spaces**

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

#### **5.6.7 Ventilation Systems**

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

### **5.7 Location and Protection of Fuel Piping (*IGF Code 5.7*)**

#### **5.7.1 Distance from the Ship's Side**

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

#### **5.7.2 Piping\***

Fuel piping is not to be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations.

#### **5.7.3 Spaces Requiring Fuel Pipe Protections**

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

#### **5.7.4 Locations of Gas Fuel Piping in *ESD* Protected Machinery Spaces**

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

#### **5.7.5 Protection of Gas Fuel Piping in *ESD* Protected Machinery Spaces**

Gas fuel piping in *ESD* protected machinery spaces is to be protected against mechanical damage.

### **5.8 Fuel Preparation Room Design (*IGF Code 5.8*)**

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

### **5.9 Bilge Systems (*IGF Code 5.9*)**

#### **5.9.1 Segregation of Bilge Systems**

Bilge systems installed in areas where fuel covered by this Part can be present are to be segregated from the bilge system of spaces where fuel cannot be present.

#### **5.9.2 Drainage Systems**

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

#### **5.9.3 Drainage Systems for Liquid Fuels**

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

## **5.10 Drip Trays (*IGF Code 5.10*)**

### **5.10.1 Arrangement**

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

### **5.10.2 Materials**

Drip trays are to be made of suitable material.

### **5.10.3 Thermic Protection**

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

### **5.10.4 Drain Valves**

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

### **5.10.5 Risk Assessment**

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

## **5.11 Arrangement of Entrances and Other Openings in Enclosed Spaces (*IGF Code 5.11*)**

### **5.11.1 Access to Hazardous Areas**

Direct access is not to 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** is to be provided.

### **5.11.2 Access to Fuel Preparation Room below the Deck**

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

### **5.11.3 Access to the Tank Connection Space**

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

### **5.11.4 Access to an *ESD*-protected Machinery Space**

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

### **5.11.5 Access to Inerted Spaces**

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

## **5.12 Airlocks (IGF Code 5.12)**

### **5.12.1 Structure**

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 **Chapters 18, 19 and 20, Part C**, the door sill is not to be less than 300 *mm* in height. The doors are to be self-closing without any holding back arrangements.

### **5.12.2 Mechanical Ventilations**

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

### **5.12.3 Design**

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

### **5.12.4 Shape**

Airlocks are to have a simple geometrical form. They are to provide free and easy passage, and to have a deck area not less than 1.5 *m*<sup>2</sup>. Airlocks are not to be used for other purposes, for instance as store rooms.

### **5.12.5 Audible and Visual Alarms**

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

### **5.12.6 Restriction of Access**

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

### **5.12.7 Essential Equipment for Safety**

Essential equipment required for safety is not to be de-energized and is to 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 (*IGF Code 6.1*)**

#### **6.1.1      General**

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

### **6.2      Functional Requirements (*IGF Code 6.2*)**

#### **6.2.1      Functional Requirements**

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

#### **6.2.2      Additional Requirements**

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

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

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

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

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

### **6.3      General Requirements (*IGF Code 6.3*)**

#### **6.3.1      General**

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

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

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

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 is to be able to safely contain leakage from the tank in case of leakage from the tank connections.

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

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

#### **6.4.15-3(1)(b).**

**7** The material of the bulkheads of the tank connection space is to have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario. The tank connection space is to 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.

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

**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.

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

**11** Means are to be provided whereby liquefied gas in the storage tanks can be safely emptied.

**12** It is to 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 is to be performed with an inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipes. See detailed requirements in **6.10**.

### **6.4 Liquefied Gas Fuel Containment (IGF Code 6.4)**

#### **6.4.1 General**

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

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

**3** The design life of portable tanks is not to be less than 20 years.

**4** Liquefied gas fuel containment systems is to 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 Society 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. (Refer to *IACS Recommendation No.34*. 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 this -4)

**5** Liquefied gas fuel containment systems are to be designed with suitable safety margins:

- (1) to withstand, in the intact condition, the environmental conditions anticipated for the liquefied gas fuel containment system's design life and the loading conditions appropriate for them, which is to include full homogeneous and partial load conditions and partial filling to any intermediate levels; and
- (2) being appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, aging and construction tolerances.

**6** The liquefied gas fuel containment system structural strength is to be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions that are to be considered for the design of each liquefied gas fuel containment system are

given in **6.4.15**. There are three main categories of design conditions:

- (1) Ultimate Design Conditions - The liquefied gas fuel containment system structure and its structural components are to withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design is to take into account proper combinations of the following loads:
  - (a) internal pressure;
  - (b) external pressure;
  - (c) dynamic loads due to the motion of the ship in all loading conditions;
  - (d) thermal loads;
  - (e) sloshing loads;
  - (f) loads corresponding to ship deflections;
  - (g) tank and liquefied gas fuel weight with the corresponding reaction in way of supports;
  - (h) insulation weight;
  - (i) loads in way of towers and other attachments; and
  - (j) test loads.
- (2) Fatigue Design Conditions - The liquefied gas fuel containment system structure and its structural components is not to fail under accumulated cyclic loading.
- (3) Accidental Design Conditions - The liquefied gas fuel containment system is to meet each of the following accident design conditions (accidental or abnormal events), addressed in this Part:
  - (a) Collision - The liquefied gas fuel containment system is to withstand the collision loads specified in **6.4.9-5(a)** without deformation of the supports or the tank structure in way of the supports likely to endanger the tank and its supporting structure.
  - (b) Fire - The liquefied gas fuel containment systems are to sustain without rupture the rise in internal pressure specified in **6.7.3-1** under the fire scenarios envisaged therein.
  - (c) Flooded compartment causing buoyancy on tank - the anti-flotation arrangements are to sustain the upward force, specified in **6.4.9-5(b)** and there is to be no endangering plastic deformation to the hull. Plastic deformation may occur in the fuel containment system provided it does not endanger the safe evacuation of the ship.

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

**8** An inspection/survey plan for the liquefied gas fuel containment system is to be developed and approved by the Society. The inspection/survey plan is to 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)(h)** or **6.4.12(2)(i)**.

**9** Liquefied gas fuel containment systems are to 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 are to be designed and built to ensure safety during operations, inspection and maintenance.

#### **6.4.2 Liquefied Gas Fuel Containment Safety Principles**

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

**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 -3 to -5 as applicable.

**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, is to be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages (a critical state means that the crack develops into unstable condition).

The arrangements are to comply with the following:

- (1) failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) are to have a sufficiently long development time for remedial actions to be taken; and
- (2) failure developments that cannot be safely detected before reaching a critical state are to have a predicted development time that is much longer than the expected lifetime of the tank.

**4** 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.

**5** For independent tanks requiring full or partial secondary barrier, means for safely disposing of leakages from the tank are to 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 are to be provided in accordance with the following table.

Table GF6.1 Tank Type and Secondary Barrier

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

#### 6.4.4 Design of Secondary Barriers

The design of the secondary barrier, including spray shield if fitted, is to 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)(f);
- (2) physical, mechanical or operational events within the liquefied gas fuel tank that could cause failure of the primary barrier are not to impair the due function of the secondary barrier, or vice versa;
- (3) failure of a support or an attachment to the hull structure 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 Society;
- (5) the methods required in (4) are to be approved by the Society and are to include, as a minimum:
  - (a) details on the size of defect acceptable and the location within the secondary barrier, before its liquid tight effectiveness is compromised;
  - (b) accuracy and range of values of the proposed method for detecting defects in (a) above;
  - (c) scaling factors to be used in determining the acceptance criteria if full-scale model testing is not undertaken; and
  - (d) effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test.



(6) the secondary barrier is to fulfil its functional requirements at a static angle of heel of 30°.

#### **6.4.5 Partial Secondary Barriers and Primary Barrier Small Leak Protection System**

1 Partial secondary barriers as permitted in **6.4.2-3** are to be used with a small leak protection system and meet all the regulations in **6.4.4**. The small leak protection system is to include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquefied gas fuel down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

2 The capacity of the partial secondary barrier is to be determined, based on the liquefied gas fuel leakage corresponding to the extent of failure resulting from the load spectrum referred to in **6.4.12(2)(f)** 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.

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.

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

#### **6.4.6 Supporting Arrangements**

1 The liquefied gas fuel tanks are to be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in **6.4.9-2 to -5**, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

2 Anti-flotation arrangements are to be provided for independent tanks and capable of withstanding the loads defined in **6.4.9-5(b)** without plastic deformation likely to endanger the hull structure.

3 Supports and supporting arrangements are to withstand the loads defined in **6.4.9-3(3)(h)** and **6.4.9-5**, but these loads need not be combined with each other or with wave-induced loads.

#### **6.4.7 Associated Structure and Equipment**

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

#### **6.4.8 Thermal Insulation\***

Thermal insulation is to be provided as required to protect the hull from temperatures below those allowable (see **6.4.13-1(1)**) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in **6.9**.

#### **6.4.9 Design Loads**

##### **1 General**

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

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

(3) Tanks, together with their supporting structure and other fixtures, are to be designed taking into account relevant combinations of the loads described below.

## 2 Permanent loads

### (1) Gravity loads

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

### (2) Permanent external loads

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

## 3 Functional loads

### (1) Loads arising from the operational use of the tank system are to be classified as functional loads.

### (2) All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, are to be considered.

### (3) As a minimum, the effects from the following criteria, as applicable, are to be considered when establishing functional loads:

- internal pressure
- external pressure
- thermally induced loads
- vibration
- interaction loads
- loads associated with construction and installation
- test loads
- static heel loads
- weight of liquefied gas fuel
- sloshing
- wind impact, wave impacts and green sea effect for tanks installed on open deck.

#### (a) Internal pressure

- i) In all cases, including **ii**),  $P_0$  is not to be less than *MARVS*.
- ii) For liquefied gas fuel tanks where there is no temperature control and where the pressure of the liquefied gas fuel is dictated only by the ambient temperature,  $P_0$  is not to be less than the gauge vapour pressure of the liquefied gas fuel at a temperature of 45°C except as follows:
  - 1) Lower values of ambient temperature may be accepted by the Society 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.
- iii) Subject to special consideration by the Society and to the limitations given in **6.4.15** for the various tank types, a vapour pressure  $P_h$  higher than  $P_0$  may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.
- iv) Pressure used for determining the internal pressure is to 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:
$$P_{eq1} = P_0 + (P_{gd})_{max} \text{ (MPa)}$$
$$P_{eq2} = P_h + (P_{gd\,site})_{max} \text{ (MPa)}$$

- v) 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)(a)** The value of internal liquid pressure  $P_{gd}$  resulting from combined effects of gravity and dynamic accelerations are to be calculated as follows:

$$P_{gd} = a_{\beta} \cdot z_{\beta} \frac{\rho}{1.02 \times 10^5} (MPa)$$

where:

$a_{\beta}$  : dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction  $\beta$  ; (see **Fig. GF6.1**). 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 **Fig. GF6.2**). Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining  $z_{\beta}$  unless the total volume of tank domes  $V_d$  does not exceed the following value:

$$V_d = V_t \frac{100 - FL}{FL}$$

where:

$V_t$  : tank volume without any domes; and

$FL$  :filling limit according to **6.8**.

$\rho$  : maximum liquefied gas fuel density ( $kg/m^3$ ) at the design temperature.

The direction that gives the maximum value  $(P_{gd})_{max}$  or  $(P_{gd\text{site}})_{max}$  is to be considered. Where acceleration components in three directions need to be considered, an ellipsoid is to be used instead of the ellipse in **Fig. GF6.1**. The above formula applies only to full tanks.

Fig. GF6.1 Acceleration Ellipsoid

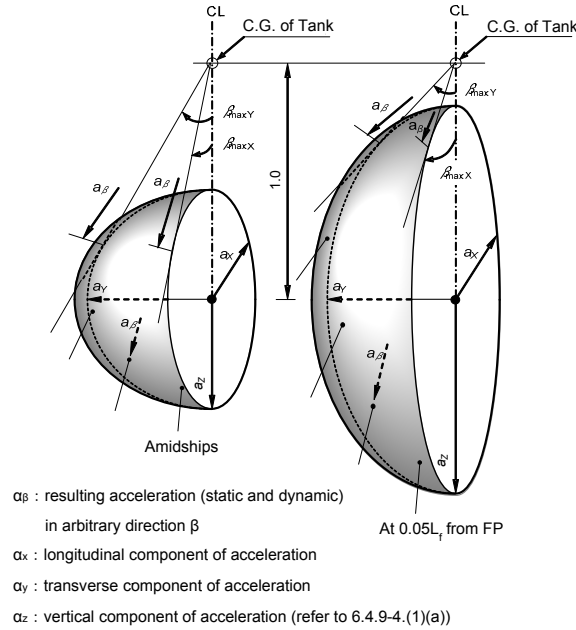
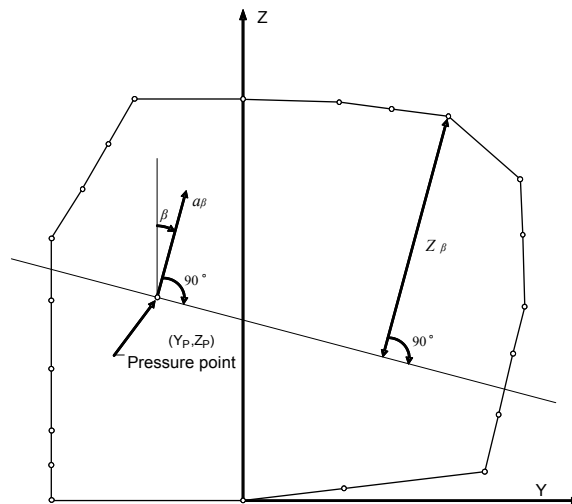


Fig. GF6.2 Determination of Internal Pressure Heads



(b) External pressure

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

(c) Thermally induced loads

- Transient thermally induced loads during cooling down periods are to be considered for tanks intended for liquefied gas fuel temperatures below -55°C.
- Stationary thermally induced loads are to be considered for liquefied gas fuel containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see 6.9.2).

(d) Vibration

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

- (e) 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, are to be considered.
- (f) Loads associated with construction and installation  
Loads or conditions associated with construction and installation are to be considered, e.g. lifting.
- (g) Test loads  
Account is to be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in **16.5**.
- (h) Static heel loads  
Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° are to be considered.
- (i) Other loads  
Any other loads not specifically addressed, which could have an effect on the liquefied gas fuel containment system, are to be taken into account.

#### 4 Environmental loads

- (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.
  - (a) Loads due to ship motion  
The determination of dynamic loads is to take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading. The ship's motion is to include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks are to be estimated at their centre of gravity and include the following components:
    - i) vertical acceleration: motion accelerations of heave, pitch and, possibly roll (normal to the ship base);
    - ii) transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and
    - iii) longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.
 Methods to predict accelerations due to ship motion are to be proposed and approved by the Society. (Refer to **4.28.2, Part N** for guidance formulae for acceleration components) Ships for restricted service may be given special consideration.
  - (b) Dynamic interaction loads  
Account is to be taken of the dynamic component of loads resulting from interaction between liquefied gas fuel containment systems and the hull structure, including loads from associated structures and equipment.
  - (c) Sloshing loads  
The sloshing loads on a liquefied gas fuel containment system and internal components be evaluated for the full range of intended filling levels.
  - (d) Snow and ice loads  
Snow and icing are to be considered, if relevant.
  - (e) Loads due to navigation in ice  
Loads due to navigation in ice are to be considered for ships intended for such service.
  - (f) Green sea loading  
Account is to be taken to loads due to water on deck.

(g) Wind loads

Account is to be taken to wind generated loads as relevant.

**5 Accidental loads**

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

(a) Collision load

The collision load is to be determined based on the fuel containment system under fully loaded condition with an inertial force corresponding to “ $a$ ” in **Table GF6.2** in forward direction and “ $a/2$ ” in the aft direction, where “ $g$ ” is gravitational acceleration.

Table GF6.2 Design Acceleration for Collision Loads

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

(b) Loads due to flooding on ship

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

**6.4.10 Structural Integrity**

**1 General**

- (1) The structural design is to ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This is to take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.
- (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.
- (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 is to be demonstrated by compliance with **6.4.16**.

**6.4.11 Structural Analysis**

**1 Analysis**

- (1) The design analyses are to be based on accepted principles of statics, dynamics and strength of materials.
- (2) Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.
- (3) When determining responses to dynamic loads, the dynamic effect is to be taken into account where it may affect structural integrity.

**2 Load scenarios**

- (1) For each location or part of the liquefied gas fuel containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously are to be considered.
- (2) The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service conditions are to be considered.

- (3) When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses are to be calculated according to:

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

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

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

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

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

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

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

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

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

#### 6.4.12 Design Conditions

All relevant failure modes are to be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this chapter, and the load scenarios are covered by 6.4.11-2.

##### (1) Ultimate design condition

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

i) Plastic deformation and buckling are to be considered.

ii) Analysis is to be based on characteristic load values as follows:

Permanent loads: Expected values

Functional loads: Specified values

Environmental loads: For wave loads: most probable largest load encountered during  $10^8$  wave encounters.

iii) For the purpose of ultimate strength assessment the following material parameters apply:

1)  $R_e$ : specified minimum yield stress at room temperature ( $N/mm^2$ ). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

2)  $R_m$ : specified minimum tensile strength at room temperature ( $N/mm^2$ ).

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective  $R_m$  and  $R_e$  of the welds, after any applied heat treatment, are to be used. In such cases the transverse weld tensile strength is to not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials are not to be incorporated in liquefied gas fuel containment systems.

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

iv) The equivalent stress  $\sigma_c$  (von Mises, Huber) is to be determined by:

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

where:

- $\sigma_x$ : 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 are to be calculated as described in **6.4.11-2(3)**.

- v) Allowable stresses for materials other than those covered by **7.4** are to be subject to approval by the Society in each case.
- vi) Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

(2) Fatigue Design Condition

- (a) The fatigue design condition is the design condition with respect to accumulated cyclic loading.
- (b) Where a fatigue analysis is required the cumulative effect of the fatigue load is to comply with:

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

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 is to be based on the design life of the tank but not less than  $10^8$  wave encounters.

- (c) Where required, the liquefied gas fuel containment system is to be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the liquefied gas fuel containment system. Consideration is to be given to various filling conditions.
- (d) Design  $S$ - $N$  curves used in the analysis are to be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned. The  $S$ - $N$  curves are to be based on a 97.6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of  $S$ - $N$  curves derived in a different way requires adjustments to the acceptable  $C_w$  values specified in **6.4.12(2)(g)** to **6.4.12(2)(i)**.
- (e) Analysis is to be based on characteristic load values as follows:  
Permanent loads: Expected values



Functional loads: Specified values or specified history

Environmental loads: Expected load history, but not less than  $10^8$  cycles

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

- (f) Where the size of the secondary barrier is reduced, as is provided for in **6.4.2-3**, fracture mechanics analyses of fatigue crack growth are to be carried out to determine:
- i) crack propagation paths in the structure, where necessitated by **6.4.12(2)(g)** to **6.4.12(2)(i)**, as applicable;
  - ii) crack growth rate;
  - iii) the time required for a crack to propagate to cause a leakage from the tank;
  - iv) the size and shape of through thickness cracks; and
  - v) 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 are to be approved by the Society.

In analysing crack propagation the largest initial crack not detectable by the inspection method applied is to be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable. Crack propagation analysis specified in **6.4.12(2)(g)** the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in **Fig. GF6.3**. Load distribution and sequence for longer periods, such as in **6.4.12(2)(h)** and **6.4.12(2)(i)** are to be approved by the Society.

The arrangements are to comply with **6.4.12(2)(g)** to **6.4.12(2)(i)** as applicable.

- (g) For failures that can be reliably detected by means of leakage detection:

$C_w$  is to be less than or equal to 0.5.

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

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

$C_w$  is to be less than or equal to 0.5.

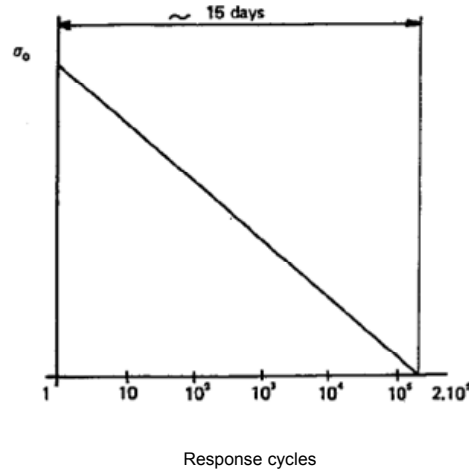
Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, is not to be less than three times the inspection interval.

- (i) In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria is to be applied as a minimum:

$C_w$  is to be less than or equal to 0.1.

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

Fig. GF6.3 Simplified Load Distribution



$\sigma_0$  = most probable maximum stress over the life of the ship  
 Response cycle scale is logarithmic; the value of  $2.10^5$  is given as an example of estimate

(3) Accidental design condition

- (a) The accidental design condition is a design condition for accidental loads with extremely low probability of occurrence.
  - (b) Analysis is to 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)(h) and 6.4.9-5 need not be combined with each other or with wave-induced loads.

### 6.4.13 Materials and Construction\*

#### 1 Materials

(1) Materials forming ship structure

- (a) To determine the grade of plate and sections used in the hull structure, a temperature calculation is to be performed for all tank types. The following assumptions are to be made in this calculation:
  - i) The primary barrier of all tanks is to be assumed to be at the liquefied gas fuel temperature.
  - ii) In addition to i) above, where a complete or partial secondary barrier is required it is to be assumed to be at the liquefied gas fuel temperature at atmospheric pressure for any one tank only.
  - iii) For ships with unrestricted areas of operation, ambient temperatures are to be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and conversely, lower values may be imposed by the Society for ships trading to areas where lower temperatures are expected during the winter months.
  - iv) Still air and sea water conditions are to be assumed, i.e. no adjustment for forced convection.
  - v) 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) are to be assumed.

- vi) The cooling effect of the rising boil-off vapour from the leaked liquefied gas fuel is to be taken into account where applicable.
  - vii) Credit for hull heating may be taken in accordance with **6.4.13-1(1)(c)**, provided the heating arrangements are in compliance with **6.4.13-1(1)(d)**.
  - viii) No credit is to be given for any means of heating, except as described in **6.4.13-1(1)(c)**.
  - ix) For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.
- (b) The materials of all hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of liquefied gas fuel temperature, is to be in accordance with **Table GF7.5**. This includes hull structure supporting the liquefied gas fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.
- (c) Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in **Table GF7.5**. In the calculations required in **6.4.13-1(1)(a)**, credit for such heating may be taken in accordance with the following principles:
- i) for any transverse hull structure;
  - ii) for longitudinal hull structure referred to in **6.4.13-1(1)(b)** 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
  - iii) as an alternative to **ii)**, 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)(c)** with the heating considered, whichever is less. In this case, the ship's longitudinal strength is to comply with the relevant requirements in other Part for both when those bulkhead(s) are considered effective and not.
- (d) The means of heating referred to in (c) are to comply with the following:
- i) the heating system is to be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to no less than 100% of the theoretical heat requirement;
  - ii) the heating system is to be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with **6.4.13-1(1)(c)i)** are to be supplied from the emergency source of electrical power; and
  - iii) the design and construction of the heating system are to be included in the approval of the containment system by the Society.

## 2 Materials of primary and secondary barriers

- (1) Metallic materials used in the construction of primary and secondary barriers not forming the hull, are to be suitable for the design loads that they may be subjected to, and be in accordance with **Table GF7.1**, **Table GF7.2** or **Table GF7.3**.
- (2) Materials, either non-metallic or metallic but not covered by **Tables GF7.1**, **Table GF7.2** and **Table GF7.3**, used in the primary and secondary barriers may be approved by the Society considering the design loads that they may be subjected to, their properties and their intended use.
- (3) Where non-metallic materials, including composites, are used for or incorporated in the primary or secondary barriers, they are to be tested for the following properties, as applicable, to ensure that they are adequate for the intended service (refer to **6.4.16**):
  - (a) compatibility with the liquefied gas fuels;

- (b) ageing;
  - (c) mechanical properties;
  - (d) thermal expansion and contraction;
  - (e) abrasion;
  - (f) cohesion;
  - (g) resistance to vibrations;
  - (h) resistance to fire and flame spread; and
  - (i) resistance to fatigue failure and crack propagation.
- (4) The above properties, where applicable, are to be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than -196°C.
- (5) Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes are also to be tested as described above.
- (6) Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier.
- 3 Thermal insulation and other materials used in liquefied gas fuel containment systems**
- (1) Load-bearing thermal insulation and other materials used in liquefied gas fuel containment systems are to be suitable for the design loads.
- (2) Thermal insulation and other materials used in liquefied gas fuel containment systems are to have the following properties, as applicable, to ensure that they are adequate for the intended service:
- (a) compatibility with the liquefied gas fuels;
  - (b) solubility in the liquefied gas fuel;
  - (c) absorption of the liquefied gas fuel;
  - (d) shrinkage;
  - (e) ageing;
  - (f) closed cell content;
  - (g) density;
  - (h) mechanical properties, to the extent that they are subjected to liquefied gas fuel and other loading effects, thermal expansion and contraction;
  - (i) abrasion;
  - (j) cohesion;
  - (k) thermal conductivity;
  - (l) resistance to vibrations;
  - (m) resistance to fire and flame spread; and
  - (n) resistance to fatigue failure and crack propagation.
- (3) The above properties, where applicable, are to be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than -196°C.
- (4) Due to location or environmental conditions, thermal insulation materials are to have suitable properties of resistance to fire and flame spread and are to be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it is to have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.
- (5) Thermal insulation that does not meet recognized standards for fire resistance may be used in fuel storage hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour

seal.

- (6) Testing for thermal conductivity of thermal insulation is to be carried out on suitably aged samples.
- (7) Where powder or granulated thermal insulation is used, measures are to be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the liquefied gas fuel containment system.

#### 6.4.14 Construction Processes

##### 1 Weld joint design

- (1) All welded joints of the shells of independent tanks are to be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds are also to be designed with full penetration.
- (2) Welding joint details for type *C* independent tanks, and for the liquid-tight primary barriers of type *B* independent tanks primarily constructed of curved surfaces, are to be as follows:
  - (a) All longitudinal and circumferential joints are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed except from very small process pressure vessels. 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.
  - (b) The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings are to be designed according to the requirements in **Chapter 10, Part D of the Rules**. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles are to be full penetration welds.

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

##### 2 Design for gluing and other joining processes

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

#### 6.4.15 Tank Types

##### 1 Type *A* independent tanks

- (1) Design basis
  - (a) Type *A* independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with the requirements in **Chapter 14, Part C of the Rules**. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure  $P_0$  is to be less than 0.07 MPa.
  - (b) A complete secondary barrier is required as defined in 6.4.3. The secondary barrier is to be designed in accordance with 6.4.4.
- (2) Structural analysis
  - (a) A structural analysis is to be performed taking into account the internal pressure as indicated in 6.4.9-3(3)(a), and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.
  - (b) For parts, such as structure in way of supports, not otherwise covered by the regulations in this Part, stresses are to be determined by direct calculations, taking into account the loads referred to in 6.4.9-2 to 6.4.9-5 as far as applicable, and the ship deflection in way of

supports.

- (c) The tanks with supports are to be designed for the accidental loads specified in **6.4.9-5**. These loads need not be combined with each other or with environmental loads.

(3) Ultimate design condition

- (a) 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, are to 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)(a)iii**. However, if detailed calculations are carried out for the primary members, the equivalent stress  $\sigma_C$ , as defined in **6.4.12(1)(a)iv**, may be increased over that indicated above to a stress acceptable to the Society. Calculations are to 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.
- (b) Tank boundary scantlings are to meet at least the requirements in **Chapter 14, Part C of the Rules** for deep tanks taking into account the internal pressure as indicated in **6.4.9-3(3)(a)** and any corrosion allowance required by **6.4.1-7**.
- (c) The liquefied gas fuel tank structure is to be reviewed against potential buckling.

(4) Accidental design condition

- (a) The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in **6.4.9-5** and **6.4.1-6(3)** as relevant.
- (b) When subjected to the accidental loads specified in **6.4.9-5**, the stress is to comply with the acceptance criteria specified in **6.4.15-1(3)**, modified as appropriate taking into account their lower probability of occurrence.

**2** Type B independent tanks

(1) Design basis

- (a) Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks) the design vapour pressure  $P_0$  is to be less than  $0.07 \text{ MPa}$ .
- (b) A partial secondary barrier with a protection system is required as defined in **6.4.3**. The small leak protection system is to be designed according to **6.4.5**.

(2) Structural analysis

- (a) The effects of all dynamic and static loads are to be used to determine the suitability of the structure with respect to:
  - i) plastic deformation;
  - ii) buckling;
  - iii) fatigue failure; and
  - iv) crack propagation.

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

- (b) A three-dimensional analysis is to be carried out to evaluate the stress levels, including interaction with the ship's hull. The model for this analysis is to include the liquefied gas fuel tank with its supporting and keying system, as well as a reasonable part of the hull.
- (c) A complete analysis of the particular ship accelerations and motions in irregular waves, and of the response of the ship and its liquefied gas fuel tanks to these forces and motions, is to be performed unless the data is available from similar ships.

(3) Ultimate design condition

- (a) Plastic deformation

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

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

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

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

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

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

where:

$\sigma_m$ : 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  $R_e/B$ ; and

$F$ : the lesser of  $R_m/C$  or  $R_e/D$

with  $R_m$  and  $R_e$  as defined in **6.4.12(1)(a)iii)**. With regard to the stresses  $\sigma_m$ ,  $\sigma_L$ ,  $\sigma_b$  and  $\sigma_g$  see also the definition of stress categories in **6.4.15-2(3)(f)**.

The values  $A$  to  $D$  are to have at least the following minimum values:

Table GF6.3 Values of  $A$ ,  $B$ ,  $C$  and  $D$  (Type *B*, Independent Tanks)

	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 figures in **Table GF6.3** may be altered considering the design condition considered in acceptance with the Society. For type *B* independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis are not to exceed:

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

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

(b) Buckling

Buckling strength analyses of liquefied gas fuel tanks subject to external pressure and other loads causing compressive stresses are to be carried out as deemed appropriate by the Society. The method is to 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.

(c) Fatigue design condition

- i) Fatigue and crack propagation assessment is to be performed in accordance with the provisions of **6.4.12(2)**. The acceptance criteria is to comply with **6.4.12(2)(g)**, **6.4.12(2)(h)** or **6.4.12(2)(i)**, depending on the detectability of the defect.
- ii) Fatigue analysis is to consider construction tolerances.
- iii) Where deemed necessary by the Society, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

(d) Accidental design condition

- i) The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in **6.4.9-5** and **6.4.1-6(3)**, as relevant.
- ii) When subjected to the accidental loads specified in **6.4.9-5**, the stress is to comply with the acceptance criteria specified in **6.4.1-15(2)(c)**, modified as appropriate, taking into account their lower probability of occurrence.

(e) Marking

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

(f) Stress categories

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

- i) Normal stress is the component of stress normal to the plane of reference.
- ii) 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.
- iii) Bending stress is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.
- iv) Shear stress is the component of the stress acting in the plane of reference.
- v) 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.
- vi) 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.
- vii) 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:

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

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

where:

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

$S_2$ : distance in the meridional direction to another region where the limits for primary general membrane stress 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.

- viii) 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.

### 3 Type C Independent Tanks

#### (1) Design basis

- (a) 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)(b)** 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.
- (b) The design vapour pressure is not to be less than:

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

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:

55N/mm<sup>2</sup>: for ferritic-perlitic, martensitic and austenitic steel;

25N/mm<sup>2</sup>: for aluminium alloy (5083-0);

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

$h$ ,  $0.75b$  or  $0.45l$ ,

with:

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

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

$l$ : length of tank (dimension in ship's longitudinal direction) (m);

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

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

- (c) The Society may allocate a tank complying with the criteria of type C tank minimum design pressure, to a type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

#### (2) Shell thickness

- (a) In considering the shell thickness the following apply:
  - i) for pressure vessels, the thickness calculated according to **6.4.15-3(2)(d)** is to be considered as a minimum thickness after forming, without any negative tolerance;
  - ii) for pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, is not to be less than 5 mm for carbon manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys; and
  - iii) the welded joint efficiency factor to be used in the calculation according to **6.4.15-3(2)(d)** is to be 0.95 when the inspection and the non-destructive testing referred to in **16.3.6-4** are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels the Society may accept partial non-destructive examinations, but not less than those of **16.3.6-4**, depending on such factors as the material used, the design temperature, the nil

ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 is to be adopted. For special materials the above-mentioned factors are to be reduced, depending on the specified mechanical properties of the welded joint.

- (b) The design liquid pressure defined in **6.4.9-3(3)(a)** is to be taken into account in the internal pressure calculations.
- (c) The design external pressure  $P_e$ , used for verifying the buckling of the pressure vessels, is not to be less than that given by:

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

where:

$P_1$ : setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves  $P_1$  is to be specially considered, but is not to 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 is to be taken into account.

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

- (d) Scantlings based on internal pressure are to 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)(a)**, including flanges, are to be determined. These calculations are to be, in all cases, based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels are to be reinforced in accordance with **Chapter 10, Part D of the Rules**.

- (e) Stress analysis in respect of static and dynamic loads is to be performed as follows:

- i) pressure vessel scantlings are to be determined in accordance with **6.4.15-3(2)(a)** to **6.4.15-3(2)(d)** and **6.4.15-3(3)**;
- ii) calculations of the loads and stresses in way of the supports and the shell attachment of the support are to be made. Loads referred to in **6.4.9-2** to **6.4.9-5** are to be used, as applicable. Stresses in way of the supports are not to exceed 90% of the yield stress or 75% of the tensile strength of the material. In special cases a fatigue analysis may be required by the Society; and
- iii) if required by the Society, secondary stresses and thermal stresses are to be specially considered.

### (3) Ultimate design condition

#### (a) Plastic deformation

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

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5f$$

$$\sigma_L + \sigma_b \leq 1.5f$$

$$\sigma_m + \sigma_b \leq 1.5f$$

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

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

where:

$\sigma_m$ : 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)(a)iii**). With regard to the stresses  $\sigma_m$ ,  $\sigma_L$ ,  $\sigma_b$  and  $\sigma_g$  see also the definition of stress categories in **6.4.15-2(3)(f)**.

The values  $A$  and  $B$  are to have at least the following minimum values:

Table 6.4 Values of  $A$  and  $B$  (Type C, Independent Tanks)

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

(b) Buckling criteria is to be as follows:

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

(c) Fatigue design condition

- For type C independent tanks where the liquefied gas fuel at atmospheric pressure is below  $-55^\circ\text{C}$ , the Society may require additional verification to check their compliance with **6.4.15-3(1)(a)**, regarding static and dynamic stress depending on the tank size, the configuration of the tank and arrangement of its supports and attachments.
- For vacuum insulated tanks, special attention is to be made to the fatigue strength of the support design and special considerations are to also be made to the limited inspection possibilities between the inside and outer shell.

(d) Accidental design condition

- The tanks and the tank supports are to be designed for the accidental loads and design conditions specified in **6.4.9-5** and **6.4.1-6(3)**, as relevant.
- When subjected to the accidental loads specified in **6.4.9-5**, the stress is to comply with the acceptance criteria specified in **6.4.15-3(3)(a)**, modified as appropriate taking into account their lower probability of occurrence.

(e) Marking

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

#### 4 Membrane tanks

(1) Design basis

- 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.
- A systematic approach, based on analysis and testing, is to be used to demonstrate that the

system will provide its intended function in consideration of the identified in service events as specified in **6.4.15-4(2)(a)**.

- (c) A complete secondary barrier is required as defined in **6.4.3**. The secondary barrier is to be designed according to **6.4.4**.
- (d) The design vapour pressure  $P_0$  is to not normally exceed  $0.025 \text{ MPa}$ . 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  $0.070 \text{ MPa}$ .
- (e) 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.
- (f) The thickness of the membranes is normally not to exceed  $10 \text{ mm}$ .
- (g) The circulation of inert gas throughout the primary and the secondary insulation spaces, in accordance with **6.11.1** is to be sufficient to allow for effective means of gas detection.

(2) Design considerations

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

- i) 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.

- ii) 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.

- iii) 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.

- (b) The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the liquefied gas fuel containment system are to be established during the design development in accordance with **6.4.15-4(1)(b)**.

(3) Loads, load combinations

Particular consideration is to 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.

- (4) Structural analyses
  - (a) Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the liquefied gas fuel containment and associated structures and equipment noted in **6.4.7** are to be performed. The structural analysis is to provide the data required to assess each failure mode that has been identified as critical for the liquefied gas fuel containment system.
  - (b) Structural analyses of the hull are to take into account the internal pressure as indicated in **6.4.9-3(3)(a)**. Special attention is to be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.
  - (c) The analyses referred to in **6.4.15-4(4)(a)** and **6.4.15-4(4)(b)** are to be based on the particular motions, accelerations and response of ships and liquefied gas fuel containment systems.
- (5) Ultimate design condition
  - (a) The structural resistance of every critical component, sub-system, or assembly, is to be established, in accordance with **6.4.15-4(1)(b)**, for in-service conditions.
  - (b) The choice of strength acceptance criteria for the failure modes of the liquefied gas fuel containment system, its attachments to the hull structure and internal tank structures, is to reflect the consequences associated with the considered mode of failure.
  - (c) The inner hull scantlings are to meet the requirements in **Chapter 14, Part C**, taking into account the internal pressure as indicated in **6.4.9-3(3)(a)** and the specified appropriate regulations for sloshing load as defined in **6.4.9-4(1)(c)**.
- (6) Fatigue design condition
  - (a) Fatigue analysis is to be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.
  - (b) The fatigue calculations are to be carried out in accordance with **6.4.12(2)**, with relevant regulations depending on:
    - i) the significance of the structural components with respect to structural integrity; and
    - ii) availability for inspection.
  - (c) For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes,  $C_w$  is to be less than or equal to 0.5.
  - (d) Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, are to satisfy the fatigue and fracture mechanics regulations stated in **6.4.12(2)(h)**.
  - (e) 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, is to satisfy the fatigue and fracture mechanics regulations stated in **6.4.12(2)(i)**.
- (7) Accidental design condition
  - (a) The containment system and the supporting hull structure are to be designed for the accidental loads specified in **6.4.9-5**. These loads need not be combined with each other or with environmental loads.
  - (b) Additional relevant accidental scenarios are to be determined based on a risk analysis. Particular attention is to be paid to securing devices inside of tanks.

#### **6.4.16 Limit State Design for Novel Concepts**

**1** Fuel containment systems that are of a novel configuration that cannot be designed using section **6.4.15** are to be designed using this section and **6.4.1** to **6.4.14**, as applicable. Fuel containment system design according to this section is to be based on the principles of limit state

design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using **6.4.15**.

**2**

- (1) The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in **6.4.1-6**. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.
- (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:

- (a) 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.
  - (b) Fatigue limit states (*FLS*), which correspond to degradation due to the effect of time varying (cyclic) loading.
  - (c) Accident limit states (*ALS*), which concern the ability of the structure to resist accidental situations.
- (3) The procedure and relevant design parameters of the limit state design are to comply with **Annex 6.4.16 “Standard for the Use of Limit State Methodologies in the Design of Fuel Containment Systems of Novel Configuration”**.

## **6.5 Portable Liquefied Gas Fuel Tanks (*IGF Code 6.5*)**

### **6.5.1 Design**

The design of the tank is to comply with **6.4.15-3**. The tank support (container frame or truck chassis) is to be designed for the intended purpose.

### **6.5.2 Location**

Portable fuel tanks are to be located in dedicated areas fitted with:

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

### **6.5.3 Fixing**

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

### **6.5.4 Consideration for Strength and the Effect of the Ship’s Stability**

Consideration is to be given to the strength and the effect of the portable fuel tanks on the ship’s stability.

### **6.5.5 Means for Connections**

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

#### **6.5.6 Limitation of Quantity of Fuel Spilled**

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

#### **6.5.7 Pressure Relief Systems**

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

#### **6.5.8 Control and Monitoring Systems**

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

#### **6.5.9 Access**

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

#### **6.5.10 Connections**

After connection to the ship's fuel piping system,

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

### **6.6 CNG Fuel Containment Systems(IGF Code 6.6)**

#### **6.6.1 Approval**

The storage tanks to be used for *CNG* are to be certified and approved by the Society.

#### **6.6.2 Pressure Relief Valves**

Tanks for *CNG* are to be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in **6.7.2-7** and **6.7.2-8**.

#### **6.6.3 Depressurization of Tanks\***

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

#### **6.6.4 Arrangement of Storage Facilities**

Storage of *CNG* in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Society provided the following **(1)** to **(3)** are fulfilled in addition to **6.3.1-4** to **6.3.1-6**:

- (1) adequate means are provided to depressurize and inert the tank in case of a fire which can affect the tank;
- (2) all surfaces within such enclosed spaces containing the *CNG* storage are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and
- (3) a fixed fire-extinguishing system is installed in the enclosed spaces containing the *CNG* storage. Special consideration is to be given to the extinguishing of jet-fires.

## 6.7 Pressure Relief System (IGF Code 6.7)

### 6.7.1 General

1 All fuel storage tanks are to be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried. Fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, are also not to be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 are to be independent of the pressure relief systems.

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

### 6.7.2 Pressure Relief Systems for Liquefied Gas Fuel Tanks\*

1 If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space is to be protected by a pressure relief device which is to 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 Society for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.

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

3 Interbarrier spaces are to be provided with pressure relief devices. For membrane systems, the designer is to demonstrate adequate sizing of interbarrier space *PRVs*.

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

5 The following temperature requirements apply to *PRVs* fitted to pressure relief systems:

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

6 In the event of a failure of a fuel tank *PRV* a safe means of emergency isolation is to be available.

- (1) procedures are to be provided and included in the operation manual (refer to chapter 18);
- (2) the procedures are to allow only one of the installed *PRVs* for the liquefied gas fuel tanks to be isolated, physical interlocks are to be included to this effect; and
- (3) isolation of the *PRV* is to be carried out under the supervision of the master. This action is to be recorded in the ship's log, and at the *PRV*.

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

- (1) so constructed that the discharge will be unimpeded and 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 is normally not to be less than  $B'/3$  or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways.



However, vent mast height could be limited to lower value according to special consideration by the Society.

**8** The outlet from the pressure relief valves is normally to 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.

**9** All other fuel gas vent outlets are also to be arranged in accordance with **6.7.2-7** and **6.7.2-8**. Means are to be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

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

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

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

**13** *PRVs* are to be connected to the highest part of the fuel tank. *PRVs* are to be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (*FL*) as given in **6.8**, under conditions of 15° list and 0.015*L<sub>f</sub>* trim.

### **6.7.3 Sizing of Pressure Relieving System**

**1** Sizing of pressure relief valves

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

- (a) 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
- (b) vapours generated under fire exposure computed using the following formula:

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

where

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

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

*F* = 1.0: for tanks without insulation located on deck;

*F* = 0.5: for tanks above the deck when insulation is approved by the Society. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);

*F* = 0.5: for uninsulated independent tanks installed in holds;

*F* = 0.2: for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

*F* = 0.1: for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds); and

*F* = 0.1: for membrane tanks.

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

*G*: gas factor according to formula:

$$G = \frac{12.4}{L_h D_h} \sqrt{\frac{ZT}{M}}$$

where

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

$L_h$ : latent heat of the material being vaporized at relieving conditions, in  $kJ/kg$ ;

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

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

where

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

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

$M$ : molecular mass of the product.

$A$ : external surface area of the tank ( $m^2$ ), as for different tank types, as shown in **Fig. GF6.4**.

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

- (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 (a) and (b) apply:
  - (a) If the pressure relief valves have to be sized for fire loads the fire factors according may be reduced to the following values:
    - i)  $F = 0.5$  to  $F = 0.25$
    - ii)  $F = 0.2$  to  $F = 0.1$
  - (b) The minimum fire factor is  $F = 0.1$
- (3) The required mass flow of air at relieving conditions is given by:

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

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

## 2 Sizing of vent pipe system

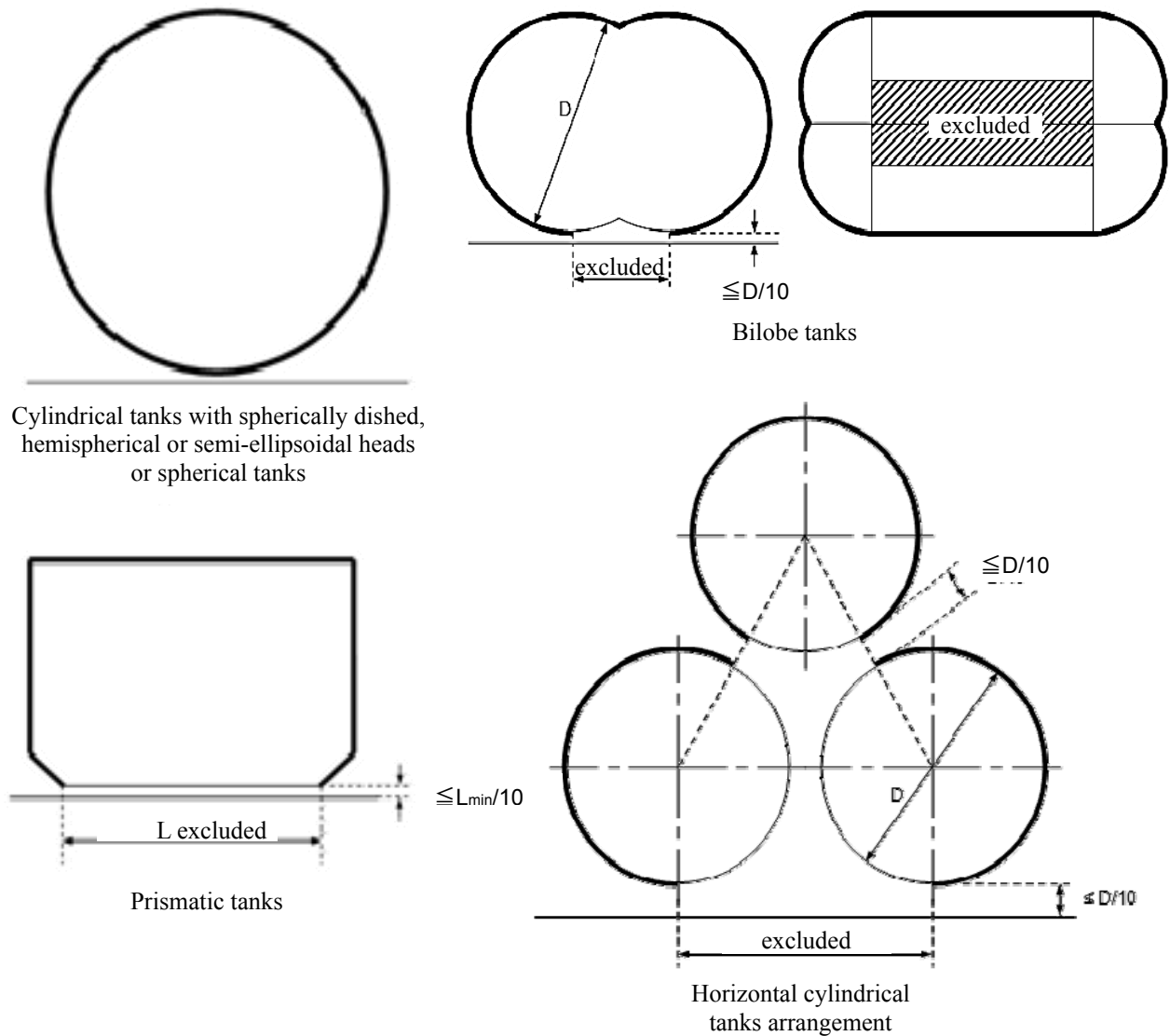
- (1) Pressure losses upstream and downstream of the *PRVs*, are to be taken into account when determining their size to ensure the flow capacity required by **6.7.3-1**.
- (2) Upstream pressure losses
  - (a) the pressure drop in the vent line from the tank to the *PRV* inlet is not to exceed 3% of the valve set pressure at the calculated flow rate, in accordance with **6.7.3-1**;
  - (b) pilot-operated *PRVs* are to be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and
  - (c) pressure losses in remotely sensed pilot lines are to be considered for flowing type pilots.
- (3) Downstream pressure losses
  - (a) Where common vent headers and vent masts are fitted, calculations are to include flow from all attached *PRVs*.
  - (b) The built-up back pressure in the vent piping from the *PRV* outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, is not to exceed the following values:
    - i) for unbalanced *PRVs*: 10% of *MARVS*;
    - ii) for balanced *PRVs*: 30% of *MARVS*; and

iii) for pilot operated *PRVs*: 50% of *MARVS*.

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

- (4) To ensure stable *PRV* operation, the blow-down is not to be less than the sum of the inlet pressure loss and 0.02 *MARVS* at the rated capacity.

Fig. GF6.4 How to Determine External Surface Areas of Tanks



## **6.8 Loading Limit for Liquefied Gas Fuel Tanks (IGF Code 6.8)**

### **6.8.1 Loading Limit**

1 Storage tanks for liquefied gas are not to be filled to more than a volume equivalent to 98 % full at the reference temperature as defined in **2.2.1-36**. A loading limit curve for actual fuel loading temperatures is to be prepared from the following formula:

$$LL = FL \frac{\rho_R}{\rho_L}$$

$LL$  : loading limit as defined in **2.2.1-27**, expressed in per cent

$FL$  : filling limit as defined in **2.2.1-16** expressed in per cent, here 98 %

$\rho_R$  : relative density of fuel at the reference temperature

$\rho_L$  : relative density of fuel at the loading temperature

2 In cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95 %. This also applies in cases where a second system for pressure maintenance is installed, (refer to **6.9**). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in **6.8.1-1** is to be used.

## **6.9 The Maintaining of Fuel Storage Condition (IGF Code 6.9)**

### **6.9.1 Control of Tank Pressure and Temperature**

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

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

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

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

### **6.9.2 Design of Systems**

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

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

### **6.9.3 Reliquefaction Systems**

1 The reliquefaction system is to be designed and calculated according to **6.9.3-2**. The system has to be sized in a sufficient way also in case of no or low consumption.

2 The reliquefaction system is to be arranged in one of the following (1) to (4) 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 are, as far as reasonably practicable, to be disposed of without venting to atmosphere.

#### **6.9.4 Thermal Oxidation Systems**

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

#### **6.9.5 Compatibility**

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

#### **6.9.6 Availability of Systems**

- 1 The availability of the system and its supporting auxiliary services are to be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the fuel tank pressure and temperature can be maintained by another service/system.
- 2 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges are to have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

### **6.10 Atmospheric Control within the Fuel Containment System (*IGF Code 6.10*)**

#### **6.10.1 Atmospheric Control within the Fuel Containment System**

- 1 A piping system is to 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 is to be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.
- 2 The system is to be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.
- 3 Gas sampling points are to be provided for each fuel tank to monitor the progress of atmosphere change.
- 4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

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

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

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

**2** Alternatively, the spaces referred to in **-1** requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand is to be provided.

## **6.12 Environmental Control of Spaces Surrounding Type C Independent Tanks (IGF Code 6.12)**

### **6.12.1 Environmental Control of Spaces Surrounding Type C Independent Tanks**

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

## **6.13 Inerting (IGF Code 6.13)**

### **6.13.1 Inerting**

Arrangements to prevent back-flow of fuel vapour into the inert gas system are to be provided as specified below:

- (1) To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line is to be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve is to be installed between the double block and bleed arrangement and the fuel system. These valves are to be located outside non-hazardous spaces.
- (2) Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in **(1)** above.
- (3) The arrangements are to be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. are to be provided for controlling pressure in these spaces.
- (4) Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means are to be provided to monitor the quantity of gas being supplied to individual spaces.

## **6.14 Inert Gas Production and Storage on Board (*IGF Code 6.14*)**

### **6.14.1 Inert Gas Production and Storage on Board\***

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

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

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

**4** Nitrogen pipes are only to be led through well ventilated spaces. Nitrogen pipes in enclosed spaces are to be fully welded, to have only a minimum of flange connections as needed for fitting of valves and to be as short as possible.

## **Chapter 7      MATERIAL AND GENERAL PIPE DESIGN**

### **7.1      Goal (*IGF Code 7.1*)**

#### **7.1.1      General**

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 (*IGF Code 7.2*)**

#### **7.2.1      General**

This chapter relates to functional requirements in **3.2.1**, **3.2.5**, **3.2.6**, **3.2.8**, **3.2.9** and **3.2.10**. In addition, **7.2.2** applies.

#### **7.2.2      Additional Requirements**

- 1** Fuel piping is to be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.
- 2** Provision is to be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.
- 3** If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid are to be fitted.
- 4** Low temperature piping is to 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      General Pipe Design (*IGF Code 7.3*)**

#### **7.3.1      General\***

- 1** Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance are to be colour marked in accordance with a standard recognized by the Society.
- 2** Where tanks or piping are separated from the ship's structure by thermal isolation, provision is to be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded.
- 3** All pipelines or components which may be isolated in a liquid full condition are to be provided with relief valves.
- 4** Pipework, which may contain low temperature fuel, is to be thermally insulated to an extent which will minimize condensation of moisture.
- 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 is only to contain piping or cabling necessary for operational purposes.



### 7.3.2 Wall Thickness\*

1 The minimum wall thickness is to be calculated as follows:

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

where:

$t_0$ : theoretical thickness

$$t_0 = PD / (2Ke + P) (mm)$$

with:

$P$ : design pressure (MPa) referred to in 7.3.3;

$D$ : outside diameter (mm);

$K$ : allowable stress (N/mm<sup>2</sup>) referred to in 7.3.4; and

$e$ : efficiency factor 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 standards recognized by the Society. In other cases an efficiency factor of less than 1.0, in accordance with standards recognized by the Society, may be required depending on the manufacturing process;

$b$ : allowance for bending (mm). The value of  $b$  is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given,  $b$  is to be:

$$b = \frac{Dt_0}{2.5r} (mm)$$

with:

$r$ : mean radius of the bend (mm);

$c$ : corrosion allowance (mm) deemed appropriate by the Society. This allowance is to be consistent with the expected life of the piping; and

$a$ : negative manufacturing tolerance for thickness (%).

2 The absolute minimum wall thickness is to be in accordance with a standard recognized by the Society.

### 7.3.3 Design Condition\*

1 The greater of the design conditions following (1) to (5) are to be used for piping, piping system and components as appropriate:

- (1) for systems or components which may be separated from their relief valves and which contain only vapour at all times, vapour pressure at 45°C assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or
- (2) the MARVS of the fuel tanks and fuel processing systems; or
- (3) the pressure setting of the associated pump or compressor discharge relief valve; or
- (4) the maximum total discharge or loading head of the fuel piping system; or
- (5) the relief valve setting on a pipeline system.

2 Piping, piping systems and components are to have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa.

### 7.3.4 Allowable Stress

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 is to be the lower of the following values:

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

where:

$R_m$  : specified minimum tensile strength at room temperature ( $N/mm^2$ ); and

$R_e$  : specified minimum yield stress at room temperature ( $N/mm^2$ ). If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

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

**3** For pipes made of materials other than steel, the allowable stress is to be considered by the Society.

**4** High pressure fuel piping systems are to have sufficient constructive strength. This is to be confirmed by carrying out stress analysis and considered following **(1)** to **(3)**.

(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.

**5** When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship is to be carried out for each branch of the piping system.

### **7.3.5 Flexibility of Piping**

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

### **7.3.6 Piping Fabrication and Joining Details\***

**1** Flanges, valves and other fittings are to comply with a standard recognized by the Society, taking into account the design pressure defined in **7.3.3-1**. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in **7.3.3-1** may be accepted.

**2** All valves and expansion joints used in high pressure fuel piping systems are to be approved by the Society.

**3** The piping system is to be joined by welding with a minimum of flange connections. Gaskets are to be protected against blow-out.

**4** Piping fabrication and joining details are to comply with the following **(1)** to **(4)**.

(1) Direct connections

(a) Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings are to be removed.

(b) Slip-on welded joints with sleeves and related welding, having dimensions in accordance with standards recognized by the Society, are only to be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than minus 55°C.

(c) Screwed couplings complying with standards recognized by the Society are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

- (2) Flanged connections
  - (a) Flanges in flange connections are to be of the welded neck, slip-on or socket welded type; and
  - (b) For all piping except open ended, the following restrictions apply:
    - i) For design temperatures colder than minus 55°C, only welded neck flanges are to be used; and
    - ii) For design temperatures colder than minus 10°C, slip-on flanges are not to be used in nominal sizes above 100 mm and socket welded flanges are not to be used in nominal sizes above 50 mm.
- (3) Expansion joints
 

Where bellows and expansion joints are provided in accordance with 7.3.6-1 the following (a) to (c) apply:

  - (a) if necessary, bellows are to be protected against icing;
  - (b) slip joints are not to be used except within the liquefied gas fuel storage tanks; and
  - (c) bellows are normally not to be arranged in enclosed spaces.
- (4) Other connections
 

Piping connections are to be joined in accordance with 7.3.6-4(1) to 7.3.6-4(3) but for other exceptional cases alternative arrangements considered by the Administration may be accepted.

## 7.4 Regulations for Materials (with reference to IGF Code 7.4)

### 7.4.1 Metallic Materials\*

1 Materials for fuel containment and piping systems are to comply with the minimum regulations given in the following tables:

- (1) **Table GF7.1:** Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.
- (2) **Table GF7.2:** Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C.
- (3) **Table GF7.3:** Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C.
- (4) **Table GF7.4:** Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to -165°C.
- (5) **Table GF7.5:** Plates and sections for hull structures required by 6.4.13-1(1)(b).

2 Materials having a melting point below 925°C are to not be used for piping outside the fuel tanks.

3 For *CNG* tanks, the use of materials not covered above may be specially considered by the Society.

4 Where required the outer pipe or duct containing high pressure gas in the inner pipe is to fulfil the material regulations for pipe materials in **Table GF7.4**.

5 The outer pipe or duct around liquefied gas fuel pipes is to fulfil the material regulations for pipe materials with design temperature down to -165°C in **Table GF7.4**.

### 7.4.2 Marking

Steels which have satisfactorily complied with the required test are to be marked with identification mark in accordance with the requirements in **Part K** and in case the impact test has been required, the impact testing temperature and “T” are to be suffixed to the markings. (Example: KL33-50T. -0T as suffix for 0°C.)

Table GF7.1 Plates, Pipes (Seamless and Welded)<sup>(1),(2)</sup>, 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 Society		
Composition limits to be approved by the Society		
Normalized, or quenched and tempered <sup>(4)</sup>		
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS		
Sampling frequency		
Plates	Each “piece” to be tested	
Sections and forgings	Each “lot” to be tested.	
Mechanical properties		
Tensile properties	Specified minimum yield stress not to exceed 410 N/mm <sup>2(5)</sup>	
Toughness (Charpy <i>V</i> -notch impact test)		
Plates	Transverse test pieces. Minimum average energy value ( <i>KV</i> ) 27 <i>J</i>	
Sections and forgings	Longitudinal test pieces. Minimum average energy value ( <i>KV</i> ) 41 <i>J</i>	
Test temperature	Thickness ( <i>mm</i> )	Test temperature(°C)
	<i>t</i> ≤ 20	0
	20 < <i>t</i> ≤ 40 <sup>(3)</sup>	-20

Notes

- (1) For seamless pipes and fittings the requirements of **Part K** applies. The use of longitudinally and spirally welded pipes is to be specially approved by the Society
- (2) Charpy *V*-notch impact tests are not required for pipes.
- (3) This Table is generally applicable for material thicknesses up to 40 *mm*. Proposals for greater thicknesses are to be approved by the Society.
- (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<sup>2</sup> may be approved by the Society. For these materials, particular attention is to be given to the hardness of the welded and heat affected zones.

Table GF7.2 Plates, Sections and Forgings<sup>(1)</sup> for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below 0°C and down to -55°C (Maximum Thickness 25 mm<sup>(2)</sup>)

Chemical composition and heat treatment				
Carbon-manganese steel (Fully killed, aluminium treated fine grain steel)				
Chemical composition (ladle analysis)				
$C$	$M_n$	$S_i$	$S$	$P$
0.16%以下 <sup>(3)</sup>	0.7~1.60%	0.10~0.50%	0.025%以下	0.025%以下
Optional additions : Alloys and grain refining elements may be generally in accordance with the following				
$N_i$	$C_\gamma$	$M_0$	$C_u$	$N_b$
0.80% max	0.25% max	0.08% max	0.35% max	0.05% max
$V$				
0.10% max				
Al content total 0.02% min (Acid soluble 0.015% min)				
Normalized, or quenched and tempered <sup>(4)</sup>				
Tensile and toughness (impact) test regulations				
Sampling frequency				
Plates	Each “piece” to be tested			
Sections and forgings	Each “lot” to be tested			
Mechanical properties				
Tensile properties	Specified minimum yield stress not to exceed 410 N/mm <sup>2(5)</sup>			
Toughness (Charpy $V$ -notch impact test) :				
Plates	Transverse test pieces. Minimum average energy value (KV) 27J			
Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41J			
	5°C below the design temperature or -20°C whichever is lower			
Test temperature				

Notes

- (1) The Charpy  $V$ -notch impact tests and chemistry regulations for forgings may be specially considered by the Society.
- (2) For material thickness of more than 25 mm, Charpy  $V$ -notch impact tests are to be conducted as follows:

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

The impact energy value is to be in accordance with the table for the applicable type of test specimen.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower.

For thermally stress relieved reinforcements and other fittings, the test temperature is to be the same as that required for the adjacent tank-shell thickness.

- (3) By special agreement with the Society, the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C
- (4) A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.
- (5) Materials with specified minimum yield stress exceeding 410 N/mm<sup>2</sup> may be approved by the Society. For these materials, particular attention is to be given to the hardness of the welded and heat affected zones.

Guidance:

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with **Table GF7.3** may be necessary.

Table GF7.3 Plates, Sections and Forgings<sup>(1)</sup> for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below -55°C and down to -165°C<sup>(2)</sup>  
(Maximum Thickness 25 mm<sup>(3),(4)</sup>)

Minimum design temp. ( ° C )	Chemical composition <sup>(5)</sup> and heat treatment	Impact test temp ( ° C )
-60	1.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6)</sup>	-65
-65	2.25%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6)(7)</sup>	-70
-90	3.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6)(7)</sup>	-95
-105	5%nickel steel - normalized or normalized and tempered or quenched and tempered <sup>(6)(7)(8)</sup>	-110
-165	9%nickel steel - double normalized and tempered or quenched and tempered <sup>(6)</sup>	-196
-165	Austenitic stainless steels, such as types 304, 304 <i>L</i> , 316, 316 <i>L</i> , 321 and 347 solution treated <sup>(9)</sup>	-196
-165	Aluminium alloys <sup>(10)</sup> : such as type 5083 annealed	Not required
-165	Austenitic <i>Fe-Ni</i> 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 “lot” to be tested	
Toughness (Charpy <i>V</i> - Notch Impact Test):		
Plates	Transverse test pieces. Minimum average energy value ( <i>KI</i> ) 27 <i>J</i>	
Sections and Forgings	Longitudinal test pieces. Minimum average energy value ( <i>KI</i> ) 41 <i>J</i>	

Notes

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

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

In no case is the test temperature to be above that indicated in **Table GF7.3**.

The minimum average energy value is to be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, minimum average energy values are to be specially considered.

- (4) For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
- (5) The chemical composition limits are to be in accordance with recognized standards deemed appropriate by the Society.
- (6) Thermo-mechanical controlled processing (TMCP) Ni steels will be subject to acceptance by the Society.
- (7) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Society.
- (8) A specially heat treated 5% Ni 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 Society.
- (10) For aluminium alloys other than type 5083, additional tests may be required to verify the toughness of the material.

Table GF7.4 Pipes (Seamless and Welded)<sup>(1)</sup>, Forgings<sup>(2)</sup> and Castings<sup>(2)</sup> for Fuel and Process Piping for Design Temperatures below 0°C and down to -165°C<sup>(3)</sup>  
(Maximum Thickness 25 mm)

Minimum design temp. (°C)	Chemical composition <sup>(5)</sup> and heat treatment	Impact test	
		Test temp.(°C)	Minimum average energy (KV)(J)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed. <sup>(6)</sup>	See note (4)	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered. <sup>(6)</sup>	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered. <sup>(6)</sup>	-95	34
-165	9% nickel steel <sup>(7)</sup> . Double normalized and tempered or quenched and tempered.	-196	41
	Austenitic stainless steels, such as types 304, 304L, 316, 316L, 321, and 347. Solution treated. <sup>(8)</sup>	-196	41
	Aluminium alloys <sup>(9)</sup> , such as type 5083 annealed		Not required
Tensile and toughness (impact) test regulations Sampling frequency Each "lot" to be tested. Toughness (Charpy V-notch impact test) Impact test: Longitudinal test pieces			

Notes

- (1) The use of longitudinally or spirally welded pipes is to be specially approved by the Society.
- (2) The regulations for forgings and castings may be subject to special consideration by the Society.
- (3) The regulations for design temperatures below -165°C are to be specially agreed with the Society.
- (4) The test temperature is to be 5°C below the design temperature or -20°C whichever is lower.
- (5) The composition limits are to be in accordance with recognized standards deemed appropriate by the Society.
- (6) A lower design temperature may be specially agreed with the Society 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 Society.
- (9) For aluminium alloys other than type 5083, additional tests may be required to verify the toughness of the material.

Table GF7.5 Plates and Sections for Hull Structures Required by 6.4.13-1(1)(b)

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above	In accordance with the relevant requirements in other Part							
-5 and above								
down to -5	15	25	30	50	25	45	50	50
down to -10	×	20	25	50	20	40	50	50
down to -20	×	×	20	50	×	30	50	50
down to -30	×	×	×	40	×	20	40	50
Below -30	In accordance with <b>Table GF7.2</b> except that the thickness limitation given in <b>Table GF7.2</b> and in footnote 2 of that table does not apply.							

Note

×: means steel grade not to be used.

## **Chapter 8      BUNKERING**

### **8.1      Goal (*IGF Code 8.1*)**

#### **8.1.1      General**

The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

### **8.2      Functional Requirements (*IGF Code 8.2*)**

#### **8.2.1      General**

This chapter relates to functional requirements in 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In addition, 8.2.2 applies.

#### **8.2.2      Piping Systems**

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

### **8.3      Bunkering Station (*IGF Code 8.3*)**

#### **8.3.1      General**

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

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

3 Arrangements are to be made for safe management of any spilled fuel.

4 Suitable means are to be provided to relieve the pressure and remove liquid contents from pump suction and bunker lines. Liquid is to be discharged to the liquefied gas fuel tanks or other suitable location.

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

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

#### **8.3.2      Ships' Fuel Hoses**

1 Liquid and vapour hoses used for fuel transfer are to be compatible with the fuel and suitable for the fuel temperature.

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



## **8.4      Manifold (*IGF Code 8.4*)**

### **8.4.1      Manifolds**

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

## **8.5      Bunkering System (*IGF Code 8.5*)**

### **8.5.1      Purging**

An arrangement for purging fuel bunkering lines with inert gas is to be provided.

### **8.5.2      Prevention of the Release of Gas**

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

### **8.5.3      Stop Valves**

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

### **8.5.4      Drainage**

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

### **8.5.5      Inerting and Gas Freeing**

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

### **8.5.6      Isolation of Bunkering Lines**

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

### **8.5.7      Ship-Shore Link (*SSL*)**

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

### **8.5.8      Adjustment of the Valve Closure Time**

If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with **16.7.3-7** from the trigger of the alarm to full closure of the remote operated valve required by **8.5.3** is to be adjusted.

## **Chapter 9      FUEL SUPPLY TO CONSUMERS**

### **9.1      Goal (*IGF Code 9.1*)**

#### **9.1.1      General**

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

### **9.2      Functional Requirements (*IGF Code 9.2*)**

#### **9.2.1      General**

This chapter is related to functional requirements in **3.2.1** to **3.2.6**, **3.2.8** to **3.2.11** and **3.2.13** to **3.2.17**. In addition, **9.2.2** applies.

#### **9.2.2      Additional Requirements**

- 1** the fuel supply system is to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;
- 2** the piping system for fuel transfer to the consumers is to be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and
- 3** fuel lines outside the machinery spaces are to be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

### **9.3      Redundancy of Fuel Supply (*IGF Code 9.3*)**

#### **9.3.1      Redundancy**

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

#### **9.3.2      Number of Tanks**

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

#### **9.3.3      Exception for Type C Tanks**

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

### **9.4      Safety Functions of Gas Supply System (*IGF Code 9.4*)**

#### **9.4.1      Location of Valves\***

Fuel storage tank inlets and outlets are to be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation which are not accessible are to be remotely operated. Tank valves whether accessible or not are to be automatically operated when the safety system required in **15.2.2-2** is activated.

#### **9.4.2 Master Gas Fuel Valves**

The main gas supply line to each gas consumer or set of consumers are to be equipped with a manually operated stop valve and an automatically operated “master gas fuel valve” coupled in series or a combined manually and automatically operated valve. The valves are to 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 is automatically to cut off the gas supply when activated by the safety system required in **15.2.2-2**.

#### **9.4.3 Operation of Master Gas Fuel Valves**

The automatic master gas fuel valve is to 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 Arrangements of Double Block and Bleed Valves**

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

- (1) the two shutoff valves are to be in series in the gas fuel pipe to the gas consuming equipment. The bleed valve is to be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or
- (2) the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

#### **9.4.5 Shutoff Valves of Double Block and Bleed Valves**

The two valves specified in **9.4.4** are to be of the fail-to-close type, while the ventilation valve is to be fail-to-open.

#### **9.4.6 Use of Double Block and Bleed Valves**

The double block and bleed valves specified in **9.4.4** are also to be used for normal stop of the engine.

#### **9.4.7 Ventilation of Gas Supply Branch Downstream of the Double Block and Bleed Valves**

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

#### **9.4.8 Shutdown Valves of Gas Supply Line**

There is to be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.

#### **9.4.9 Valve Functions**

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

#### **9.4.10 Protection Against Rupture\***

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

### **9.5 Fuel Distribution Outside of Machinery Space (*IGF Code 9.5*)**

#### **9.5.1 Fuel Pipes\***

Where fuel pipes pass through enclosed spaces in the ship, they are to 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 is to be mechanically underpressure ventilated with 30 air changes per hour, and gas detection as required in **15.8** is to be provided. Other solutions providing an equivalent safety level may also be accepted by the Society.

#### **9.5.2 Vent Pipes**

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

### **9.6 Fuel Supply to Consumers in Gas-safe Machinery Spaces (*IGF Code 9.6*)**

#### **9.6.1 Fuel Piping\***

Fuel piping in gas-safe machinery spaces is to be completely enclosed by a double pipe or duct fulfilling one of the conditions following **(1)** to **(3)**.

- (1) the gas piping is to be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system is to be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or
- (2) the gas fuel piping is to be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors are to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited; or
- (3) other solutions providing an equivalent safety level may also be accepted by the Society.

#### **9.6.2 Connecting\***

The connecting of gas piping and ducting to the gas injection valves are to be completely covered by the ducting. The arrangement is to facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.

## **9.7 Gas Fuel Supply to Consumers in ESD-protected Machinery Spaces (IGF Code 9.7)**

### **9.7.1 Limit of Internal Pressure**

The pressure in the gas fuel supply system is to not exceed 1.0 MPa.

### **9.7.2 Design Pressure**

The gas fuel supply lines are to have a design pressure not less than 1.0 MPa.

## **9.8 The Design of Ventilated Duct, Outer Pipe against Inner Pipe Gas Leakage (IGF Code 9.8)**

### **9.8.1 Design Pressure of Outer Pipes or Ducts**

The design pressure of the outer pipe or duct of fuel systems is not to be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct is not to 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 Design Pressure of High-pressure Fuel Piping**

**1** For high-pressure fuel piping the design pressure of the ducting is to be taken as the higher of the following **(1)** and **(2)**.

- (1) the maximum built-up pressure: static pressure
- (2) local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure given by the following expression:

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

where:

$p_0$ : maximum working pressure of the inner pipe

$k$ :  $C_p/C_v$  constant pressure specific heat divided by the constant volume specific heat

$k$ : 1.31 for CH<sub>4</sub>

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

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

### **9.8.3 Verification of the Strength**

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

### **9.8.4 Testing and Dimension of Ducts**

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

## **9.9 Compressors and Pumps (IGF Code 9.9)**

### **9.9.1 Bulkhead Penetrations**

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

### **9.9.2 Compressors and Pumps**

Compressors and pumps are to be suitable for their intended purpose. All equipment and machinery are to be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would include following **(1)** to **(4)**, 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 Introduction Prevention of Liquefied Gas**

Arrangements are to be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

### **9.9.4 Accessories and Instrumentation**

Compressors and pumps are to be fitted with accessories and instrumentation necessary for efficient and reliable function.

## **Chapter 10      POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS**

### **10.1      Goal (*IGF Code 10.1*)**

#### **10.1.1      General**

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

### **10.2      Functional Requirements (*IGF Code 10.2*)**

#### **10.2.1      General**

This chapter is related to functional requirements in **3.2.1**, **3.2.11**, **3.2.13**, **3.2.16** and **3.2.17**. In addition, **10.2.2** applies.

#### **10.2.2      Additional Requirements\***

- 1** The exhaust systems are to be configured to prevent any accumulation of un-burnt gaseous fuel.
- 2** Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture are to be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces.
- 3** The explosion venting is to be led away from where personnel may normally be present.
- 4** All gas consumers are to have a separate exhaust system.

### **10.3      Internal Combustion Engines of Piston Type (*IGF Code 10.3*)**

#### **10.3.1      General\***

- 1** The exhaust system is to 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.
- 2** For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out and reflected in the safety concept of the engine.
- 3** Each engine other than two-stroke crosshead diesel engines is to be fitted with vent systems independent of other engines for crankcases and sumps.
- 4** Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means are to be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere.
- 5** For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit is to be verified.
- 6** A means is to 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.
- 7** For engines starting on fuels covered by this Part, 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 is to be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system is to be provided.

### 10.3.2 Dual Fuel Engines

1 In case of shutoff of the gas fuel supply, the engines is to be capable of continuous operation by oil fuel only without interruption.

2 An automatic system is to 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 is to be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine is automatically to change to oil fuel mode. Manual activation of gas system shutdown is always to be possible.

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

### 10.3.3 Gas-only Engines

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

### 10.3.4 Multi-fuel Engines

1 In case of shutoff of one fuel supply, the engines are to be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power.

2 An automatic system is to be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability is to be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine is automatically to change to an alternative fuel mode. Manual activation is always to be possible.

Table GF10.1 Gas Combustion Engines

	GAS ONLY		DUAL FUEL	MULTI FUEL
IGNITION MEDIUM	Spark	Pilot fuel	Pilot fuel	N/A
MAIN FUEL	Gas	Gas	Gas and/ or Oil fuel	Gas and/ or Liquid

## 10.4 Main and Auxiliary Boilers (IGF Code 10.4)

### 10.4.1 Forced Draught Systems

Each boiler is to have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

### 10.4.2 Combustion Chambers

Combustion chambers and uptakes of boilers are to be designed to prevent any accumulation of gaseous fuel.

### 10.4.3 Burners

Burners are to be designed to maintain stable combustion under all firing conditions.



#### **10.4.4 Automatic Fuel Changeover**

On main/propulsion boilers an automatic system is to be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

#### **10.4.5 Combustion**

Gas nozzles and the burner control system are to be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Society to light on gas fuel.

#### **10.4.6 Fuel Cut-off**

There are to be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

#### **10.4.7 Valves**

On the fuel pipe of each gas burner a manually operated shutoff valve is to be fitted.

#### **10.4.8 Inerting**

Provisions are to 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 Monitoring Systems**

The automatic fuel changeover system required by **10.4.4** is to be monitored with alarms to ensure continuous availability.

#### **10.4.10 Re-ignition**

Arrangements are to be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

#### **10.4.11 Manual Purge**

Arrangements are to be made to enable the boilers purging sequence to be manually activated.

### **10.5 Gas Turbines (*IGF Code 10.5*)**

#### **10.5.1 Pressure Relief Devices**

Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems are to 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 are to be lead to a safe location, away from personnel.

#### **10.5.2 Gas-tight Enclosure**

The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the *ESD* principle outlined in **5.6** and **9.7**, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.

#### **10.5.3 Gas Detectors and Shutdown Functions**

Gas detection systems and shutdown functions are to be as outlined for *ESD* protected machinery spaces.

#### **10.5.4 Ventilation**

Ventilation for the enclosure is to be as outlined in **chapter 13** for *ESD* protected machinery

spaces, but is in addition to be arranged with full redundancy ( $2 \times 100\%$  capacity fans from different electrical circuits).

#### **10.5.5 Automatic Switching for Fuel**

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

#### **10.5.6 Combustion Failure**

Means are to be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply is to be shutdown.

#### **10.5.7 Automatic Shutdown**

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

## Chapter 11 FIRE SAFETY

### 11.1 Goal (*IGF Code 11.1*)

#### 11.1.1 General

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 (*IGF Code 11.2*)

#### 11.2.1 General

This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

### 11.3 Fire Protection (*IGF Code 11.3*)

#### 11.3.1 General

**1** Any space containing equipment for the fuel preparation such as pumps, compressors, heat exchangers, vaporizers and pressure vessels are to be regarded as a machinery space of category *A* for fire protection purposes.

**2** Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, are to be shielded by “A-60” class divisions. The “A-60” class divisions are to extend up to the underside of the deck of the navigation bridge, and any boundaries above that, including navigation bridge windows, are to have “A-0” class divisions. In addition, fuel tanks are to be segregated from cargo in accordance with the requirements of the International Maritime Dangerous Goods Code (*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 is to be considered a *class 2.1* package.

**3** The space containing fuel containment system is to be separated from the machinery spaces of category *A* or other rooms with high fire risks. The separation is to be done by a cofferdam of at least 900 mm with insulation of “A-60” class. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system is to be considered as a machinery space of category *A*, in accordance with **Chapter 9, Part R**. The boundary between spaces containing fuel containment systems is to be either a cofferdam of at least 900 mm or “A-60” class division. For type *C* tanks, the fuel storage hold space may be considered as a cofferdam.

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

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

**6** The bunkering station is to 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”.

7 If an emergency shutdown system (ESD) protected machinery spaces is separated by a single boundary, the boundary is to be of “A-60” class division.

## **11.4 Fire Main (*IGF Code 11.4*)**

### **11.4.1 General**

1 The water spray system required in 11.5 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.

2 When the fuel storage tank is located on the open deck, isolating valves are to be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main is not to deprive the fire line ahead of the isolated section from the supply of water.

## **11.5 Water Spray System (*IGF Code 11.5*)**

### **11.5.1 General**

1 A water spray system is to be installed for cooling and fire prevention to cover exposed parts of fuel storage tank located on open deck.

2 The water spray system is also to provide coverage for boundaries of the superstructures, compressor rooms, pump-rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks unless the tank is located 10 *metres* or more from the boundaries.

3 The system is to 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.

4 Stop valves are to be fitted in the water spray application main supply line, 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.

5 The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

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 is to be provided.

7 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system are to be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

8 The nozzles are to be of an approved full bore type and they are to be arranged to ensure an effective distribution of water throughout the space being protected.

## **11.6 Dry Chemical Powder Fire-extinguishing System (*IGF Code 11.6*)**

### **11.6.1 General**

1 A permanently installed dry chemical powder fire-extinguishing system is to be installed in the bunkering station area to cover all possible leak points. The capacity is to be at least 3.5  $kg/s$  for a

minimum of 45 s. The system is to be arranged for easy manual release from a safe location outside the protected area.

**2** In addition to any other portable fire extinguishers that may be required elsewhere in **Part R**, one portable dry powder extinguisher of at least 5 kg capacity is to be located near the bunkering station.

## **11.7 Fire Detection and Alarm System (*IGF Code 11.7*)**

### **11.7.1 General**

**1** A fixed fire detection and fire alarm system complying with **Chapter 29, Part R** is to be provided for the fuel storage hold spaces and the ventilation trunk to the tank connection space and in the tank connection space, and for all other rooms of the fuel gas system where fire cannot be excluded.

**2** Smoke detectors alone are not to be considered sufficient for rapid detection of a fire.

## **Chapter 12    EXPLOSION PREVENTION**

### **12.1    Goal (*IGF Code 12.1*)**

#### **12.1.1    General**

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 (*IGF Code 12.2*)**

#### **12.2.1    General**

This chapter is related to functional requirements in **3.2.2** to **3.2.5**, **3.2.7**, **3.2.8**, **3.2.12** to **3.2.14** and **3.2.17**. In addition, **12.2.2** applies.

#### **12.2.2    Additional Requirements**

The probability of explosions is to be reduced to a minimum by the following **(1)** and **(2)**:

- (1) Reducing number of sources of ignition; and
- (2) Reducing the probability of formation of ignitable mixtures.

### **12.3    General (*IGF Code 12.3*)**

#### **12.3.1    General**

Hazardous areas on open deck and other spaces not addressed in this chapter are to be decided based on applicable requirements of **Chapter 4, Part H**. The electrical equipment fitted within hazardous areas is to be according to **4.2.4, Part H**.

#### **12.3.2    Electrical Equipment and Cables**

Electrical equipment and wiring is in general not to be installed in hazardous areas unless essential for operational purposes in accordance with **4.2.4, Part H**.

#### **12.3.3    Electrical Equipment in *ESD*-protected Machinery Spaces**

Electrical equipment fitted in an *ESD*-protected machinery space is to fulfil the following **(1)** and **(2)**:

- (1) In addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans are to be certified safe for hazardous area zone 1; and
- (2) All electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 are to be automatically disconnected, if gas concentrations above 40% *LEL* is detected by two detectors in the space containing gas-fuelled consumers.

### **12.4    Hazardous Areas (*IGF Code 12.4*)**

#### **12.4.1    General**

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 Classification of Hazardous Areas\***

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 in accordance with the requirements of 12.5.

#### **12.4.3 Ventilation Ducts**

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

### **12.5 Hazardous Area Zones (*IGF Code 12.5*)**

#### **12.5.1 Hazardous Area Zone 0**

Hazardous areas zone 1 include, but are 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\***

Hazardous areas zone 1 include, but are not limited to:

- (1) Tank connection spaces, fuel storage hold spaces and interbarrier spaces;
- (2) Fuel preparation room arranged with ventilation according to 13.6;
- (3) Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet, 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;
- (5) Areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;
- (6) Enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes, semi-enclosed bunkering stations;
- (7) The *ESD*-protected machinery space is considered a non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1;
- (8) A space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and
- (9) Except for type *C* tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.

#### **12.5.3 Hazardous Area Zone 2\***

Hazardous areas zone 2 include, but are not limited to

- (1) Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.
- (2) Space containing bolted hatch to tank connection space.

## **Chapter 13     VENTILATION**

### **13.1     Goal (*IGF Code 13.1*)**

#### **13.1.1     General**

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 (*IGF Code 13.2*)**

#### **13.2.1     General**

This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

### **13.3     General Requirements (*IGF Code 13.3*)**

#### **13.3.1     Ventilation of Hazardous Areas\***

Any ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces. The ventilation is to function at all temperatures and environmental conditions the ship will be operating in.

#### **13.3.2     Electric Motors for Ventilation Fans**

Electric motors for ventilation fans are not to be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

#### **13.3.3     Design of Ventilation Fans Serving Spaces Containing Gas Sources\***

Design of ventilation fans serving spaces containing gas sources is to fulfil the following (1) to (3):

- (1) Ventilation fans are not to produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction defined as:
  - (a) impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;
  - (b) impellers and housings of non-ferrous metals;
  - (c) impellers and housings of austenitic stainless steel;
  - (d) 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
  - (e) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.
- (2) In no case is the radial air gap between the impeller and the casing to 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 is not to be used in these places.

#### **13.3.4 Separation of Ventilation Systems**

Ventilation systems required to avoid any gas accumulation are to consist of independent fans, each of sufficient capacity, unless otherwise specified in this Part.

#### **13.3.5 Air Inlets for Hazardous Enclosed Spaces**

Air inlets for hazardous enclosed spaces are to be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1.5 *m* away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gas-tight and have over-pressure relative to this space.

#### **13.3.6 Air Outlets from Non-hazardous Spaces**

Air outlets from non-hazardous spaces are to be located outside hazardous areas.

#### **13.3.7 Air Outlets from Hazardous Enclosed Spaces**

Air outlets from hazardous enclosed spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

#### **13.3.8 Required Capacity of the Ventilation Plant**

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 Areas with Entry Openings to a Hazardous Area\***

Non-hazardous spaces with entry openings to a hazardous area are to be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation is to be arranged according to the following:

- (1) During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it is to be required following **(a)** and **(b)**:
  - (a) proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and
  - (b) pressurize the space.
- (2) Operation of the overpressure ventilation is to be monitored and in the event of failure of the overpressure ventilation is to be required to following **(a)** and **(b)**:
  - (a) an audible and visual alarm are to be given at a manned location; and
  - (b) if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a standard recognized by the Society is to be required.

#### **13.3.10 Non-hazardous Areas with Entry Openings to a Hazardous Enclosed Space**

Non-hazardous spaces with entry openings to a hazardous enclosed space are to be arranged with an airlock and the hazardous space are to be maintained at underpressure relative to the

non-hazardous space. Operation of the extraction ventilation in the hazardous space is to be monitored and in the event of failure of the extraction ventilation is to be required to following (1) and (2):

- (1) an audible and visual alarm is to be given at a manned location; and
- (2) if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a standard recognized by the Society in the non-hazardous space is to be required.

### **13.4 Tank Connection Space (*IGF Code 13.4*)**

#### **13.4.1 Mechanical Forced Ventilation Systems**

The tank connection space is to be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour is to be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations is to be demonstrated by a risk assessment.

#### **13.4.2 Ventilation Trunks**

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

### **13.5 Machinery Spaces (*IGF Code 13.5*)**

#### **13.5.1 Ventilation Systems for Machinery Spaces Containing Gas-fuelled Consumers**

The ventilation system for machinery spaces containing gas-fuelled consumers is to be independent of all other ventilation systems.

#### **13.5.2 Ventilation Systems for *ESD* Protected Machinery Spaces**

*ESD* protected machinery spaces is to have ventilation with a capacity of at least 30 air changes per hour. The ventilation system is to ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces are ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

#### **13.5.3 Redundancy of Ventilation Systems\***

For *ESD* protected machinery spaces the ventilation arrangements is to provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard recognized by the Society.

#### **13.5.4 Ventilation Fans**

The number and power of the ventilation fans for *ESD* protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

## **13.6 Fuel Preparation Room (*IGF Code 13.6*)**

### **13.6.1 Ventilation Systems for Fuel Preparation Rooms**

Fuel preparation rooms, are to be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

### **13.6.2 Ventilation Fans**

The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

### **13.6.3 Operation of Ventilation Systems**

Ventilation systems for fuel preparation rooms, are to be in operation when pumps or compressors are working.

## **13.7 Bunkering Station (*IGF Code 13.7*)**

Bunkering stations that are not located on open deck are to 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 is to be provided in accordance with the risk assessment required by **8.3.1-1**.

## **13.8 Ducts and Double Pipes (*IGF Code 13.8*)**

### **13.8.1 Ducts and Double Pipes Containing Fuel Piping**

Ducts and double pipes containing fuel piping are to be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not applicable to double pipes in the engine-room if fulfilling **9.6.1(1)**.

### **13.8.2 Ventilation Systems for Double Piping and for Gas Valve Unit Spaces in Gas Safe Engine-rooms**

The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms is to be independent of all other ventilation systems.

### **13.8.3 Ventilation Inlets**

The ventilation inlet for the double wall piping or duct is always to be located in a non-hazardous area away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water.

### **13.8.4 Capacities of the Ventilation**

The capacity of the ventilation for a pipe duct or double wall piping may be below 30 air changes per hour if a flow velocity of minimum 3 *m/s* is ensured. The flow velocity is to be calculated for the duct with fuel pipes and other components installed.

## **Chapter 14     ELECTRICAL INSTALLATIONS**

### **14.1     Goal (*IGF Code 14.1*)**

#### **14.1.1     General**

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 (*IGF Code 14.2*)**

#### **14.2.1     General**

This chapter is related to functional requirements in **3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18**. In addition, **14.2.2** applies.

#### **14.2.2     Additional Requirements**

Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

### **14.3     General Requirements (*IGF Code 14.3*)**

#### **14.3.1     Electrical Installations**

Electrical installations are to be in compliance with applicable requirements of **Part H**.

#### **14.3.2     Limits of Electrical Installations in Hazardous Areas**

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

#### **14.3.3     Installation Requirements of Electrical Equipment in Hazardous Areas**

Where electrical equipment is installed in hazardous areas as provided in **14.3.2**, it is to be explosion-protected electrical equipment of certified safe type complying with **2.16, Part H**.

#### **14.3.4     Failure Modes and Effects Analysis\***

Failure modes and effects of single failure for electrical generation and distribution systems in **14.2** is to be analysed and documented to a standard recognized by the Society.

#### **14.3.5     Lighting Systems**

The lighting system in hazardous areas is to be divided between at least two branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a non-hazardous area.

#### **14.3.6     Bonding**

The installation on board of the electrical equipment units are to be such as to ensure the safe bonding to the hull of the units themselves.

#### **14.3.7 Low-liquid Level Alarm**

Arrangements are to be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown is to give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

#### **14.3.8 Automatic Isolation of Motors**

Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors are to be capable of being isolated from their electrical supply during gas-freeing operations.

#### **14.3.9 Electrical Installations in Specific Non-hazardous Areas**

For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type is to be de-energized upon loss of overpressure in the space.

#### **14.3.10 Electrical Equipment in Spaces Protected by Airlocks**

Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, are to be of a certified safe type.

## **Chapter 15     CONTROL, MONITORING AND SAFETY SYSTEMS**

### **15.1     Goal (*IGF Code 15.1*)**

#### **15.1.1     General**

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

### **15.2     Functional Requirements (*IGF Code 15.2*)**

#### **15.2.1     General**

This chapter is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.11**, **3.2.13** to **3.2.15**, **3.2.17** and **3.2.18**. In addition, **15.2.2** applies.

#### **15.2.2     Additional Requirements\***

- 1** The control, monitoring and safety systems of the gas-fuelled installation are to 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 is to be arranged to close down the gas supply system automatically, upon failure in systems as described in **Table GF15.1** and upon other fault conditions which may develop too fast for manual intervention.
- 3** For *ESD* protected machinery configurations the safety system is to shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space.
- 4** The safety functions are to be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal.
- 5** The safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop.
- 6** Where two or more gas supply systems are required to meet the requirements, each system is to be fitted with its own set of independent gas control and gas safety systems.

### **15.3     General (*IGF Code 15.3*)**

#### **15.3.1     Reading of Parameters**

Suitable instrumentation devices are to be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.

#### **15.3.2     Level Indicators and Temperature Sensors in Bilge Well**

A bilge well in each tank connection space of an independent liquefied gas storage tank is to be provided with both a level indicator and a temperature sensor. Alarm is to be given at high level in

the bilge well. Low temperature indication is to activate the safety system.

### **15.3.3 Monitoring Systems for Tanks not Permanently Installed in Ships**

For tanks not permanently installed in the ship a monitoring system is to be provided as for permanently installed tanks.

## **15.4 Bunkering and Liquefied Gas Fuel Tank Monitoring (*IGF Code 15.4*)**

### **15.4.1 Level Indicators for Liquefied Gas Fuel Tanks**

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

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

**3** Liquefied gas fuel tank liquid level gauges may be of the following types:

- (1) indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or
- (2) closed devices, which do not penetrate the liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices;

### **15.4.2 Overflow Control**

**1** Each liquefied gas fuel tank is to be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

**2** An additional sensor operating independently of the high liquid level alarm is automatically to 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 is to be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high level alarms is to be conducted by raising the fuel liquid level in the liquefied gas fuel tank to the alarm point.

**4** All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, are to be capable of being functionally tested. Systems are to be tested prior to fuel operation in accordance with **17.5.4-2**.

**5** Where arrangements are provided for overriding the overflow control system, they are to be such that inadvertent operation is prevented. When this override is operated continuous visual indication is to be provided at the navigation bridge, continuously manned central control station or onboard safety centre.

### **15.4.3 Pressure Reading Gauges for Vapour Space of Tanks**

The vapour space of each liquefied gas fuel tank is to be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control station or onboard safety centre.

### **15.4.4 Mark of Permissible Pressure in Tanks**

The pressure indicators are to be clearly marked with the highest and lowest pressure permitted

in the liquefied gas fuel tank.

#### **15.4.5 Pressure Alarms**

A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm are to be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms are to be activated before the set pressures of the safety valves are reached.

#### **15.4.6 Fuel Pump Discharge Lines and Vapour Fuel Manifolds**

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

#### **15.4.7 Pressure Indicators for Manifold**

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

#### **15.4.8 Pressure Indicator s for Fuel Storage Hold Spaces and Interbarrier Spaces**

Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere are to be provided with pressure indicator.

#### **15.4.9 Indicating of Pressure Indicators**

At least one of the pressure indicators provided is to be capable of indicating throughout the operating pressure range.

#### **15.4.10 Protective Devices for Submerged Fuel-pump Motors**

For submerged fuel-pump motors and their supply cables, arrangements are to be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown is to give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

#### **15.4.11 Fuel Temperature Measuring Positions**

Except for independent tanks of type *C* supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank is to be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.

### **15.5 Bunkering Control (*IGF Code 15.5*)**

#### **15.5.1 Remote Monitoring and Control**

Control of the bunkering is to be possible from a safe location remote from the bunkering station. At this location, monitoring, control and indication specified in the following (1) to (3) are to be capable of being carried out.

- (1) Monitoring of the tank pressure, tank temperature if required by 15.4.11, and tank level
- (2) Control of remotely controlled valves required by 8.5.3 and 11.5.1-7
- (3) Indication of overfill alarms and automatic shutdown



### **15.5.2 Stopping Alarms of Ventilations in Ducts**

If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm are to be provided at the bunkering control location, see also **15.8**.

### **15.5.3 Gas Detection Alarms of Ventilations in Ducts**

If gas is detected in the ducting around the bunkering lines an audible and visual alarm and emergency shutdown are to be provided at the bunkering control location.

## **15.6 Gas Compressor Monitoring (*IGF Code 15.6*)**

### **15.6.1 Gas Compressors\***

Gas compressors are to be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms are to include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

### **15.6.2 Shaft Glands and Bearings\***

Temperature monitoring for the bulkhead shaft glands and bearings are to be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

## **15.7 Gas Engine Monitoring (*IGF Code 15.7*)**

### **15.7.1 Indicators**

In addition to the instrumentation required in accordance with **Part D**, indicators are to be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

- (1) operation of the engine in case of gas-only engines; or
- (2) operation and mode of operation of the engine in the case of dual fuel engines.

## **15.8 Gas Detection (*IGF Code 15.8*)**

### **15.8.1 Arrangements of Gas Detectors**

Permanently installed gas detectors are to 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) ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in **4.2**.

### **15.8.2 Redundant Gas Detection Systems**

In each *ESD*-protected machinery space, redundant gas detection systems are to be provided.

### **15.8.3 Number of Gas Detectors**

The number of detectors in each space is to be considered taking into account the size, layout and ventilation of the space.

### **15.8.4 Arrangements of Gas Detectors**

The detection equipment is to be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test is to be used to find the best arrangement.

### **15.8.5 Design, Installation and Test for Gas Detection Equipment\***

Gas detection equipment is to be designed, installed and tested in accordance with a standard recognized by the Society.

### **15.8.6 Set Points of Alarm and Safety Systems**

An audible and visible alarm is to be activated at a gas vapour concentration of 20% of the lower explosion limit (*LEL*). The safety system is to be activated at 40% of *LEL* at two detectors (see **footnote 1** in **Table GF15.1**).

### **15.8.7 Set Points of Alarm and Safety Systems in Ventilated Ducts**

For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% *LEL*. The safety system is to be activated at 60% of *LEL* at two detectors (see **footnote 1** in **Table GF15.1**).

### **15.8.8 Locations of Alarms**

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

### **15.8.9 Capability of Gas Detection**

Gas detection required by this **15.8** is to be continuous without delay.

## **15.9 Fire Detection (*IGF Code 15.9*)**

### **15.9.1 Fire Detection**

Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in **Table GF15.1** below.

## **15.10 Ventilation (*IGF Code 15.10*)**

### **15.10.1 Alarms\***

Any loss of the required ventilating capacity is to give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre.

### **15.10.2 Safety Systems**

For *ESD* protected machinery spaces the safety system is to be activated upon loss of ventilation in engine-room.

## **15.11 Safety Functions of Fuel Supply Systems (*IGF Code 15.11*)**

### **15.11.1 Activation of Automatic Valves**

If the fuel supply is shut off due to activation of an automatic valve, the fuel supply is not to be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect is to be placed at the operating station for the shutoff valves in the fuel supply lines.

### **15.11.2 Fuel Leak**

If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply is not to be operated until the leak has been found and dealt with. Instructions to this effect are to be placed in a prominent position in the machinery space.

### **15.11.3 Heavy Lifting**

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

### **15.11.4 Emergency Stop**

Compressors, pumps and fuel supply are to be arranged for manual remote emergency stop from the following **(1)** to **(6)** locations as applicable:

- (1) navigation bridge;
- (2) cargo control room;
- (3) onboard safety centre;
- (4) engine control room;
- (5) fire control station; and
- (6) adjacent to the exit of fuel preparation rooms.

The gas compressor is also to be arranged for manual local emergency stop.

Table GF15.1 Monitoring of Gas Supply System to Engines

Parameter	Alarm	Automatic shutdown of tank valve <sup>6)</sup>	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 <sup>1)</sup> 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 <sup>1)</sup> in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X <sup>2)</sup>		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors <sup>1)</sup> in fuel preparation room at 40% LEL	X	X <sup>2)</sup>		
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 <sup>1)</sup> in duct inside machinery space containing gas-fuelled engines at 60% LEL	X		X <sup>3)</sup>	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 <sup>1)</sup> in ESD protected machinery space containing gas-fuelled engines at 40% LEL	X		X	It is also to disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X <sup>2)</sup>	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines <sup>5)</sup>	X		X <sup>3)</sup>	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 <sup>4)</sup>	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X <sup>4)</sup>	
Manually activated emergency shutdown of engine	X		X	

- 1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.
- 2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
- 3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
- 4) Only double block and bleed valves to close.
- 5) If the duct is protected by inert gas (see **9.6.1(1)**) then loss of inert gas overpressure is to lead to the same actions as given in this table.
- 6) Valves referred to in **9.4.1**.

## Chapter 16 MANUFACTURE, WORKMANSHIP AND TESTING

### 16.1 General (*IGF Code 16.1*)

#### 16.1.1 General\*

1 The manufacture, testing, inspection and documentation are to be in accordance with the requirements of relevant Parts and this Part.

2 Where post-weld heat treatment is specified or required, the properties of the base material is to be determined in the heat treated condition, in accordance with the applicable tables of **Chapter 7**, and the weld properties are to be determined in the heat treated condition in accordance with **16.3**. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Society.

### 16.2 General Test Regulations and Specifications (with reference to *IGF Code 16.2*)

#### 16.2.1 Tensile Test\*

1 Tensile testing is to be carried out in accordance with the requirements of **Chapter 2, Part K** for base metals and **Chapter 3, Part M** for welds.

2 Tensile strength, yield stress and elongation are to be to the satisfaction of the Society. For carbon-manganese steel and other materials with definitive yield points, consideration is to be given to the limitation of the yield to tensile ratio.

#### 16.2.2 Toughness Test\*

1 Acceptance tests for metallic materials are to include Charpy *V*-notch impact tests unless otherwise specified by the Society. The specified Charpy *V*-notch impact test requirements are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy *V*-notch impact test specimens are to be in accordance with the requirements in **Chapter 2, Part K**. The testing and regulations for specimens smaller than 5.0 mm in size are to be as deemed appropriate by the Society. Minimum average values for sub-sized specimens are to be in accordance with **Table GF16.1**.

Table GF16.1

Charpy <i>V</i> -notch specimen size	Minimum average energy of three specimens
10×10mm	<i>KV</i>
10×7.5mm	5/6 <i>KV</i>
10×5.0mm	2/3 <i>KV</i>

where:

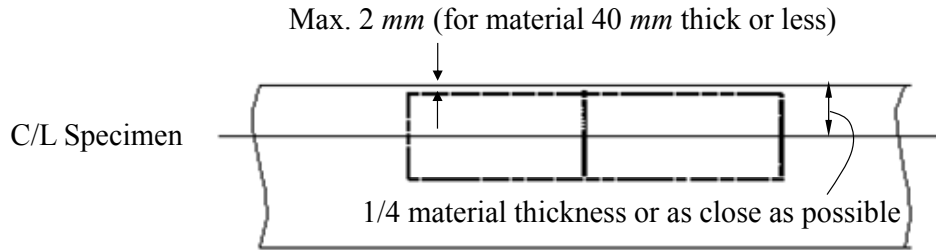
*KV*: the minimum average energy values (*J*) specified in **Tables 7.1** to **7.4**.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

2 For base metal, the largest size Charpy *V*-notch impact test specimens possible for the material thickness are to be machined with the specimens located as near as practicable to a point midway

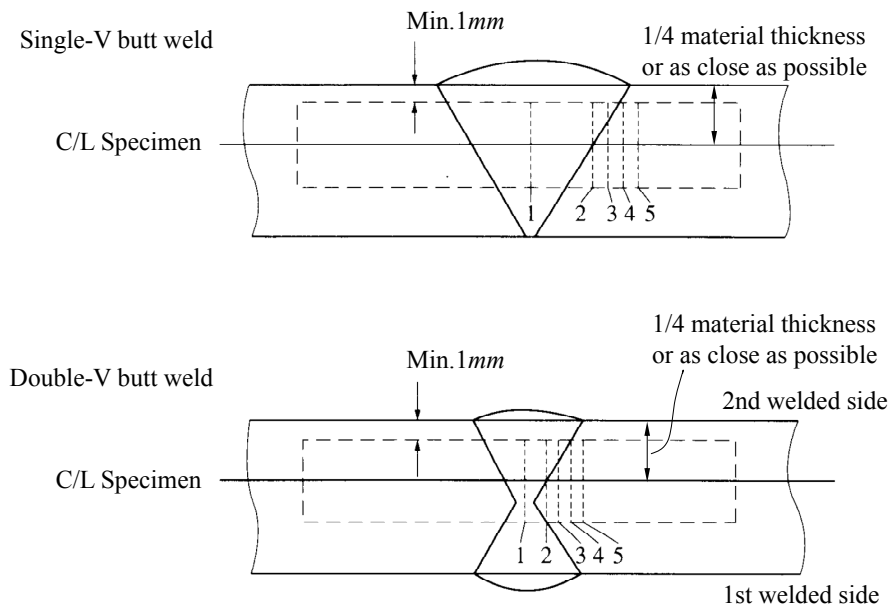
between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in **Fig GF16.1**.

Fig. GF16.1 Orientation of Base Metal Test Specimen



**3** For a weld test specimen, the largest size Charpy *V*-notch impact test specimens possible for the material thickness are to be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases the distance from the surface of the material to the edge of the specimen is to be approximately 1 mm or greater. In addition, for double-*V* butt welds, specimens are to be machined closer to the surface of the second welded section. The specimens are to be taken generally at each of the following locations, as shown in **Fig. GF16.2**, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.

Fig. GF16.2 Orientation of Weld Test Specimen



Notch locations in **Fig. GF16.2**:

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.

4 If the average value of the three initial Charpy *V*-notch impact test 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 the new average obtained from the six specimens complies with the requirements as well as 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, then the piece or lot may be accepted.

### **16.2.3 Bend Test**

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 is to be done in accordance with **Chapter 3, Part M**.

2 The bend tests are to be transverse bend tests, which may be face, root or side bends at the discretion of the Society. 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 Society, and they are to be carried out as deemed appropriate by the Society, where required.

## **16.3 Welding of Metallic Materials and Non-destructive Testing for the Fuel Containment System (with reference to *IGF Code* 16.3)**

### **16.3.1 General\***

This section is to apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and austenitic stainless steels, but these tests may be adapted for other materials. At the discretion of the Society, impact testing of austenitic 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 are to be in accordance with the requirements in **Chapter 6, Part M**. Deposited weld metal tests and butt weld tests are to be required for all consumables. The results obtained from tensile and Charpy *V*-notch impact tests are to be in accordance with the requirements in **Chapter 6, Part M**. The chemical composition of the deposited weld metal is to be recorded for information.

### **16.3.3 Welding Procedure Tests for Fuel Tanks and Process Pressure Vessels\***

1 Welding procedure tests for fuel tanks and process pressure vessels are required subject to the following -2 to -5 for all butt welds.

2 The test assemblies are to be representative of:

- (1) each base material;
- (2) each type of consumable and welding process; and
- (3) each welding position.

3 For butt welds in plates, the test assemblies are to be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test is to be in accordance with the requirements of **Chapter 11, Part D** and **Chapter 4, Part M**.



Non-destructive tests are to be in accordance with the requirements in **Chapter 11, Part D** and **Chapter 4, Part M**.

**4** The following welding procedure tests for fuel tanks and process pressure vessels are to be done in accordance with **16.2** with specimens made from each test assembly:

- (1) Cross-weld tensile tests;
- (2) Longitudinal all-weld testing where required by the requirements in **Chapter 4, Part M**;
- (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 impact test specimens, generally at each of the following locations, as shown in **Fig. GF16.2**:
  - (a) centreline of the welds;
  - (b) fusion line;
  - (c) 1 mm from the fusion line;
  - (d) 3 mm from the fusion line; and
  - (e) 5 mm from the fusion line;
- (5) Macrosection, microsection and hardness survey may also be required.

**5** Each test is to satisfy the following:

- (1) Tensile tests: cross-weld tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. For aluminium alloys, reference is to be made to **6.4.12(1)(a)iii** with regard to the regulations for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture is to be recorded for information;
- (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 impact tests are to be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy value (*KV*), is to be no less than 27J. The weld metal regulations for sub-size specimens and single energy values are to be in accordance with **16.2.2**. The results of fusion line and heat affected zone impact tests are to show a minimum average energy value (*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 value (*KV*) is to be in accordance with **16.2.2**. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards are to be to the satisfaction of the Society.

**6** Procedure tests for fillet welding are to be in accordance with the requirements in **Chapter 11, Part D** and **Chapter 4, Part M**. In such cases, consumables are to be so selected that exhibit satisfactory impact properties.

**7** Procedure tests for all welding of secondary barriers are to be in accordance with the requirements in **Chapter 4, Part M**.

#### **16.3.4 Welding Procedure Tests for Piping\***

Welding procedure tests for piping are to be carried out and are to be similar to those detailed for fuel tanks in **16.3.3**.

#### **16.3.5 Production Weld Tests\***

**1** For all fuel tanks and process pressure vessels except membrane tanks, production weld tests

are to generally be performed for approximately each 50 m of butt-weld joints and are to be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks are to be performed, except that the number of tests may be reduced subject to agreement with the Society. Tests, other than those specified in -2 to -5 may be required for fuel tanks or secondary barriers.

**2** The production tests for types *A* and *B* independent tanks are to include bend tests and, where required for procedure tests, one set of three Charpy *V*-notch impact tests. The tests are to be made for each 50 m of weld. The Charpy *V*-notch impact tests are to be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches are to be in the centre of the weld.

**3** For type *C* independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in -2. Tensile tests are to meet regulation **16.3.3-5**.

**4** The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the production welds as defined in the material manufacturers quality manual (QM).

**5** The test regulations for membrane tanks are the same as the applicable test regulations listed in **16.3.3**.

#### **16.3.6 Non-destructive Testing\***

**1** All test procedures and acceptance standards are to be to the satisfaction of the Society, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing is to be used in principle to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but in addition supplementary radiographic testing at selected locations are to be carried out to verify the results. Radiographic and ultrasonic testing records are to be retained.

**2** For type *A* independent tanks where the design temperature is below -20°C, and for type *B* independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of fuel tanks are to be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in -1.

**3** In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, is to be examined by magnetic particle or dye penetrant methods as considered necessary.

**4** For type *C* independent tanks, the extent of non-destructive testing is to be total or partial according to the requirements of **Chapter 11, Part D of the Rules**, but the controls to be carried out is not to be less than the following:

(1) Total non-destructive testing referred to in **6.4.15-3(2)(a)iii)**

Radiographic testing:

all butt welds over their full length.

Non-destructive testing for surface crack detection:

all welds over 10% of their length;

reinforcement rings around holes, nozzles, etc. over their full length.

As an alternative, ultrasonic testing, as described in -1, may be accepted as a partial substitute for the radiographic testing. In addition, the Society may require total ultrasonic testing or non-destructive testing for internal imperfections on welding of reinforcement rings around holes, nozzles, etc.

(2) Partial non-destructive testing referred to in **6.4.15-3(2)(a)iii**:

Radiographic testing:

all butt welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed.

Non-destructive testing for surface crack detection:

reinforcement rings around holes, nozzles, etc. over their full length.

Ultrasonic testing:

as may be required by the Society in each instance.

**5** The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM).

**6** Inspection of piping is to be carried out in accordance with the regulations of **Chapter 7**.

**7** The secondary barrier is to be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell are to be tested by radiographic testing.

**8** For membrane tanks, special weld inspection procedures and acceptance criteria are to be to the satisfaction of the Society.

## **16.4 Other Regulations for Construction in Metallic Materials (*IGF Code 16.4*)**

### **16.4.1 General**

Inspection and non-destructive testing of welds are to be in accordance with regulations in **16.3.5** and **16.3.6**. Where higher standards or tolerances are assumed in the design, they are also to 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, are to comply with **Chapter 11, Part D**. The tolerances are also to be related to the buckling analysis referred to in **6.4.15-2(3)(a)** and **6.4.15-3(3)(b)**.

### **16.4.3 Secondary Barriers**

During construction the regulations for testing and inspection of secondary barriers are to be approved or accepted by the Society (see also **6.4.4-5** and **6.4.4-6**).

### **16.4.4 Membrane Tanks**

The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures are to be developed during the prototype testing programme.

## **16.5 Testing (*IGF Code 16.5*)**

### **16.5.1 Testing and Inspections during Construction**

**1** All liquefied gas fuel tanks and process pressure vessels are to be subjected to hydrostatic or

hydro-pneumatic pressure testing in accordance with **16.5.2** to **16.5.5**, as applicable for the tank type.

**2** All tanks are to be subject to a tightness test which may be performed in combination with the pressure test referred to in **-1**.

**3** The gas tightness of the fuel containment system with reference to **6.3.1-3** is to be tested.

**4** Regulations with respect to inspection of secondary barriers are to be decided by the Society in each case, taking into account the accessibility of the barrier (see also **6.4.4**).

**5** The Society may require that for ships fitted with novel type *B* independent tanks, or tanks designed according to **6.4.16** at least one prototype tank and its support are to be instrumented with strain gauges or other suitable equipment to confirm stress levels during the testing required in **16.5.1-1**. Similar instrumentation may be required for type *C* independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

**6** The overall performance of the fuel containment system is to be verified for compliance with the design parameters during the first LNG bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements deemed appropriate by the Society. Records of the performance of the components and equipment, essential to verify the design parameters, are to be maintained on board and be available to the Society.

**7** The fuel containment system is to be inspected for cold spots during or immediately following the first LNG bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out as deemed appropriate by the Society.

**8** Heating arrangements, if fitted in accordance with **6.4.13-1(1)(c)** and **(d)**, are to be tested for required heat output and heat distribution.

#### **16.5.2 Type A Independent Tanks**

All type *A* independent tanks are to be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test is to be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the *MARVS*. When a hydropneumatic test is performed, the conditions are to simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.

#### **16.5.3 Type B Independent Tanks**

Type *B* independent tanks are to be subjected to a hydrostatic or hydro-pneumatic pressure testing as follows:

- (1) The test is to be performed as required in **16.5.2** for type *A* independent tanks.
- (2) In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions is to 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 is to be monitored by the use of strain gauges or other suitable equipment.

#### **16.5.4 Type C Independent Tanks and Other Pressure Vessels**

**1** Each pressure vessel is to be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than  $1.5 P_0$ . In no case during the pressure test is to 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 is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

**2** The temperature of the water used for the test is to be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

**3** The pressure is to be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

**4** Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in **-1** to **-3**.

**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 **-1** is to be fully complied with.

**6** After completion and assembly, each pressure vessel and its related fittings are to be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in **-1** or **-4** as applicable.

**7** Pneumatic testing of pressure vessels other than liquefied gas fuel tanks is to be considered on an individual case basis. Such testing is only to be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

### **16.5.5 Membrane Tanks**

#### **1 Design development testing**

- (1) The design development testing required in **6.4.15-4(1)(b)** is to include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads at all filling levels. 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 are to represent the most extreme service conditions the liquefied gas fuel containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in **6.4.4** may be based on the results of testing carried out on the prototype scaled model.
- (2) The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes is to be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure is to be determined by analyses or tests.

#### **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, are to be hydrostatically tested.
- (2) All hold structures supporting the membrane are to 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 (IGF Code 16.6)**

### **16.6.1 General**

Welding is to be carried out in accordance with **16.3**.

### **16.6.2 Post-weld Heat Treatment**

Post-weld heat treatment is to be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Society may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

### **16.6.3 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 requirements in this Chapter, the tests are to be required following **(1)** to **(4)**:

- (1) 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with following **(a)** to **(e)**:
  - (a) design temperatures colder than minus 10°C; or
  - (b) design pressure greater than 1.0 MPa; or
  - (c) gas supply pipes in ESD protected machinery spaces; or
  - (d) inside diameters of more than 75 mm; or
  - (e) wall thicknesses greater than 10 mm.
- (2) When such butt welded joints of piping sections are made by automatic welding procedures approved by the Society, 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 is to be increased to 100% and is to include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently.
- (3) The radiographic or ultrasonic inspection requirements may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.
- (4) For other butt-welded joints of pipes not covered by **16.6.3.1** and **16.6.3.3**, spot radiographic or ultrasonic inspection or other non-destructive tests are to be carried out depending upon service, position and materials to the satisfaction of the Society. In general, at least 10% of butt-welded joints of pipes are to be subjected to radiographic or ultrasonic inspection.

## **16.7 Testing (IGF Code 16.7)**

### **16.7.1 Type Testing of Piping Components\***

Each type of piping component intended to be used at a working temperature below minus 55°C is to be subject to the type tests following **(1)** to **(4)**:

- (1) Each size and type of valve are to be subjected to seat tightness testing over the full range of operating pressures and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates are to be to the requirements of the Society. During the testing satisfactory operation of the valve is to be verified.
- (2) The flow or capacity is to be certified to a standard recognized by the Society for each size and

type of valve.

- (3) Pressurized components are to be pressure tested to at least 1.5 times the design pressure.
- (4) For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing is to include a fire test to standards recognized by the Society.

#### **16.7.2 Expansion Bellows**

The following (1) to (4) type tests are to 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) and where required by the Society, on those installed within the fuel tanks:

- (1) Elements of the bellows, not pre-compressed, but axially restrained is to be pressure tested at not less than five times the design pressure without bursting. The duration of the test is not to be less than five minutes.
- (2) A pressure test is to be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.
- (3) A cyclic test (thermal movements) is to be performed on a complete expansion joint, which is to withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.
- (4) A cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 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**

**1** The requirements for testing in this section apply to fuel piping inside and outside the fuel tanks. However, relaxation from these requirements for piping inside fuel tanks and open ended piping may be accepted by the Society.

**2** After assembly, all fuel piping is to be subjected to a strength test with a suitable fluid. The test pressure is to be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board are to be tested to at least 1.5 times the design pressure.

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

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

**5** All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, are to be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Society.

**6** Emergency shutdown valves in liquefied gas piping systems are to close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics are to be available on board, and the closing time is to be verifiable and repeatable.

**7** The closing time of the valve referred to in 8.5.8 and 15.4.2.2 (i.e. time from shutdown signal

initiation to complete valve closure) is not to be greater than:

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

*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 is to be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant.



## **Chapter 17     OPERATING REQUIREMENTS**

### **17.1     Goal**

#### **17.1.1     General Requirements**

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.

### **17.2     Functional Requirements**

#### **17.2.1     General**

This chapter relates to the functional requirements in **3.2.1** to **3.2.3**, **3.2.9**, **3.2.11**, **3.2.15**, **3.2.16** and **3.2.17**. In addition, **17.2.2** applies.

#### **17.2.2     Additional Requirements**

- 1** A copy of *IGF Code*, or national regulations incorporating the provisions of *IGF Code*, is to be on board every ship covered by this Part.
- 2** Maintenance procedures and information for all gas related installations are to be available on board.
- 3** The ship is to be provided with operational procedures including a suitably detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems.
- 4** The ship is to be provided with suitable emergency procedures.

### **17.3     Fuel Handling Manual and Mounting**

#### **17.3.1     Fuel Handling Manual**

The fuel handling manual required by **17.2.2-3** is to include following **(1)** to **(9)** but is not limited to:

- (1)** Overall operation of the ship from dry-dock to dry-dock, including procedures for system cool down and warm up, bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing;
- (2)** Bunker temperature and pressure control, alarm and safety systems;
- (3)** System limitations, cool down rates and maximum fuel storage tank temperatures prior to bunkering, including minimum fuel temperatures, maximum tank pressures, transfer rates, filling limits and sloshing limitations;
- (4)** Operation of inert gas systems;
- (5)** Firefighting and emergency procedures: operation and maintenance of firefighting systems and use of extinguishing agents;
- (6)** Specific fuel properties and special equipment needed for the safe handling of the particular fuel;

- (7) Fixed and portable gas detection operation and maintenance of equipment;
- (8) Emergency shutdown and emergency release systems, where fitted; and
- (9) A description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover.

### **17.3.2 Mounting**

A fuel system schematic/piping and instrumentation diagram (P&ID) are to be reproduced and permanently mounted in the ship's bunker control station and at the bunker station.

## **17.4 Maintenance and Repair Procedures**

### **17.4.1 General**

- 1 Maintenance and repair procedures are to include considerations with respect to the tank location and adjacent spaces (see **Chapter 5**).
- 2 The procedures and information required by **17.2.2-2** are to include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas.

## **17.5 Operating Requirements**

### **17.5.1 Application**

The provisions in **17.5** are not related to surveys necessary for the maintenance of classification, but indicate those matters which are to be strictly observed by the shipowner or the ship master as well as all other persons responsible for the ship's operation.

### **17.5.2 Survey, Maintenance and Testing**

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**.

### **17.5.3 Inspection and Maintenance of Electrical Installations\***

The inspection and maintenance of electrical installations in explosion hazardous spaces are to be performed in accordance with a standard recognized by the Society.

### **17.5.4 Bunkering Operation\***

#### **1 Responsibility**

- (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) is to do following **(a)** to **(c)**:
  - (a) 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;
  - (b) agree in writing action to be taken in an emergency; and
  - (c) complete and sign the bunker safety check-list.
- (2) Upon completion of bunkering operations the ship PIC is to receive and sign a Bunker Delivery Note for the fuel delivered, containing at least the information specified in the annex to *IGF Code* part C-1, completed and signed by the bunkering source PIC.

#### **2 Pre-bunkering verification**

- (1) Prior to conducting bunkering operations, pre-bunkering verification including, but not limited

to the following, is to be carried out and documented in the bunker safety checklist:

- (a) all communications methods, including ship shore link (*SSL*), if fitted;
- (b) operation of fixed gas and fire detection equipment;
- (c) operation of portable gas detection equipment;
- (d) operation of remote controlled valves; and
- (e) inspection of hoses and couplings.

- (2) Documentation of successful verification is to be indicated by the mutually agreed and executed bunkering safety checklist signed by both PIC's.

### **3 Ship bunkering source communications**

- (1) Communications are to be maintained between the ship PIC and the bunkering source PIC at all times during the bunkering operation. In the event that communications cannot be maintained, bunkering is to stop and not resume until communications are restored.
- (2) Communication devices used in bunkering are to comply with standards for such devices recognized by the Society.
- (3) PIC's are to have direct and immediate communication with all personnel involved in the bunkering operation.
- (4) The ship shore link (*SSL*) or equivalent means to a bunkering source provided for automatic *ESD* communications, is to be compatible with the receiving ship and the delivering facility *ESD* system.

### **4 Electrical bonding**

Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering are to be electrically continuous, suitably insulated and are to provide a level of safety compliant with standards recognized by the Society.

### **5 Conditions for transfer**

- (1) Warning signs are to be posted at the access points to the bunkering area listing fire safety precautions during fuel transfer.
- (2) During the transfer operation, personnel in the bunkering manifold area are to be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations are to wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer is to be cause to stop operations and transfer is not to be resumed until all required conditions are met.
- (3) Where bunkering is to take place via the installation of portable tanks, the procedure is to provide an equivalent level of safety as integrated fuel tanks and systems. Portable tanks are to be filled prior to loading on board the ship and are to be properly secured prior to connection to the fuel system.
- (4) For tanks not permanently installed in the ship, the connection of all necessary tank systems (piping, controls, safety system, relief system, etc.) to the fuel system of the ship is part of the "bunkering" process and is to be finished prior to ship departure from the bunkering source. Connecting and disconnecting of portable tanks during the sea voyage or manoeuvring is not permitted.

## **17.5.5 Enclosed Space Entry\***

**1** Under normal operational circumstances, personnel are not to enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of an explosive atmosphere.

**2** Personnel entering any space designated as a hazardous area are not to introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

#### **17.5.6 Inerting and Purging of Fuel Systems**

**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.

**2** Procedures for inerting and purging of fuel systems are to ensure that air is not introduced into piping or a tank containing gas atmospheres, and that gas is not introduced into air contained in enclosures or spaces adjacent to fuel systems.

#### **17.5.7 Hot Work on or near Fuel Systems**

Hot work in the vicinity of fuel tanks, fuel piping and insulation systems that may be flammable, contaminated with hydrocarbons, or that may give off toxic fumes as a product of combustion is only to be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained.

## Annex 6.4.16 STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF FUEL CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION (*IGF Code, Annex*)

### 1 General

**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, **Part GF of the Rules**.

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

**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.

**4** 6.4.1 through to 6.4.14, **Part GF of the Rules** are to be complied with as applicable depending on the fuel containment system concept.

### 2 Design Format

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

$$L_d \leq R_d$$

A design load  $F_{dk}$  is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where:

$\gamma_f$  : is load factor; and

$F_k$  : is the characteristic load as specified in section 6.4.9 through to 6.4.12, **Part GF of the Rules**.

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:

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

where  $q$  denotes the functional relationship between load and load effect determined by structural analyses.

The design resistance  $R_d$  is determined as follows:

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

where:

$R_k$ : is the characteristic resistance. In case of materials covered by **Chapter 7, Part GF of the Rules**, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;

$\gamma_R$ : is the resistance factor, defined as;

$$\gamma_R = \gamma_m \cdot \gamma_s$$

$\gamma_m$ : 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** Fuel containment design is to take into account potential failure consequences. Consequence classes are defined in **Table 1**, to specify the consequences of failure when the mode of failure is related to the Ultimate Limit State, the Fatigue Limit State, or the Accident Limit State.

Table 1 Consequence Classes

Consequence class	Definition
Low	Failure implies minor release of the fuel.
Medium	Failure implies release of the fuel and potential for human injury.
High	Failure implies significant release of the fuel and high potential for human injury/fatality.

### 3 Required Analyses

**1** Three-dimensional finite element analyses are to be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes are to be identified to avoid unexpected failures. Hydrodynamic analyses are to be carried out to determine the particular ship accelerations and motions in irregular waves, and the response of the ship and its fuel containment systems to these forces and motions.

**2** Buckling strength analyses of fuel tanks subject to external pressure and other loads causing compressive stresses are to be carried out in accordance with recognized standards. The method is to 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** Fatigue and crack propagation analysis is to be carried out in accordance with **5-1**.

### 4 Ultimate Limit States (ULS)

**1** Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength are to be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance (dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities).

**2** Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads are to be considered in the analysis. At least two load combinations with partial load factors as given in **Table 2** are to be used for the assessment of the ultimate limit states.

Table 2 Partial Load Factors

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

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

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

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

**5** The load factors and the resistance factors used are to be such that the level of safety is equivalent to that of the fuel containment systems as described in sections **6.4.2-1 to -5, Part GF of the Rules**. This may be carried out by calibrating the factors against known successful designs.

**6** The material factor is to, 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, Part GF of the Rules**, the material factor may be taken as:

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

**7** The partial resistance factors  $\gamma_{si}$  are to, 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.

(1) For design against excessive plastic deformation using the limit state criteria given in **-8**, the partial resistance factors are to be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = \text{Min} \left( \frac{R_m}{R_e} \cdot \frac{B}{A}, 1.0 \right)$$

$$\kappa_2 = \text{Min} \left( \frac{R_m}{R_e} \cdot \frac{D}{C}, 1.0 \right)$$

Factors  $A$ ,  $B$ ,  $C$  and  $D$  are defined in **6.4.15-2(3)(a), Part GF of the Rules**.  $R_m$  and  $R_e$  are

defined in 6.4.12(1)(a)iii), Part GF of the Rules.

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

**8 Design against excessive plastic deformation**

- (1) Stress acceptance criteria given below refer to elastic stress analyses.
- (2) Parts of fuel containment systems where loads are primarily carried by membrane response in the structure are to satisfy the following limit state criteria:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

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

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

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

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

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

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

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

Guidance Note:

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

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\sigma_{Lxy} + \sigma_{bxy})^2}$$

- (3) Parts of fuel containment systems where loads are primarily carried by bending of girders, stiffeners and plates, are to satisfy the following limit state criteria:

$$\sigma_{ms} + \sigma_{bp} \leq 1.25F$$

$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F$$

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

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 Society 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

The stresses  $\sigma_{ms}$ ,  $\sigma_{bp}$ ,  $\sigma_{bs}$  and  $\sigma_{bt}$  are defined in (4).

Guidance Note:

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

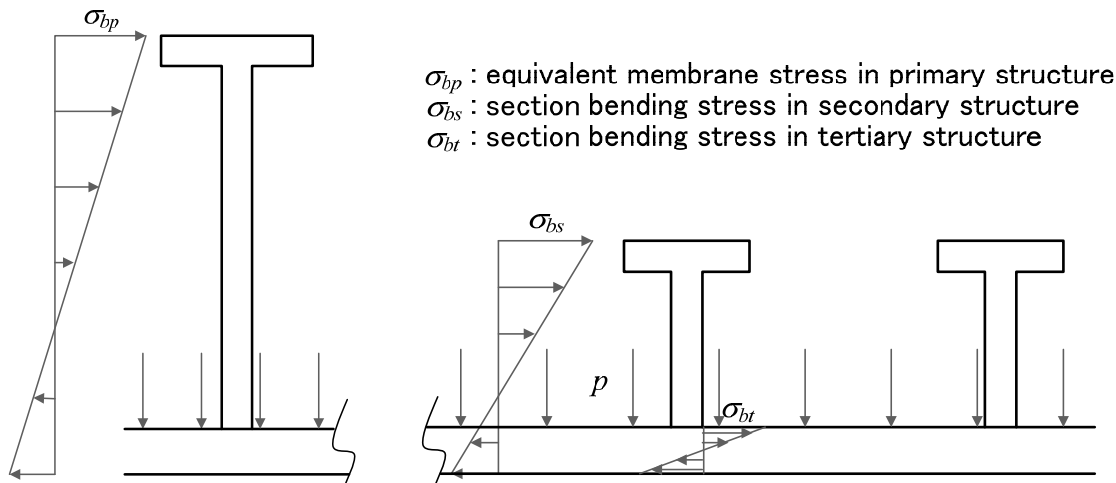
Skin plates are to be designed in accordance with the requirements of the Society. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity is to be appropriately considered in addition.

#### (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 (2). 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 Fig. 1.

Fig. 1 Definition of the three categories of section stress  
(Stresses  $\sigma_{bp}$  and  $\sigma_{bs}$  are normal to the cross section shown.)



9 The same factors  $\gamma_C$ ,  $\gamma_m$ ,  $\gamma_{si}$  are to be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case the overall level of safety is not to be less than given by these factors.

## 5 Fatigue Limit States (FLS)

1 Fatigue design condition as described in 6.4.12(2), Part GF of the Rules is to be complied

with as applicable depending on the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under **6.4.16, Part GF of the Rules** and this standard.

2 The load factors for *FLS* are to be taken as 1.0 for all load categories.

3 Consequence class factor  $\gamma_C$  and resistance factor  $\gamma_R$  are to be taken as 1.0.

4 Fatigue damage is to be calculated as described in **6.4.12(2)(b) to 6.4.12(2)(e), Part GF of the Rules**. The calculated cumulative fatigue damage ratio for the fuel containment systems is to be less than or equal to the values given in **Table 3**.

Table 3 Maximum allowable cumulative fatigue damage ratio

$C_w$	Consequence class		
	Low	Medium	High
	1.0	0.5	0.5*

Note\*: Lower value is to be used in accordance with **6.4.12(2)(g) to 6.4.12(2)(i), Part GF of the Rules**, depending on the detectability of defect or crack, etc.

5 Lower values may be fixed by the Society.

6 Crack propagation analyses are required in accordance with **6.4.12(2)(f) to 6.4.12(2)(i), Part GF of the Rules**. The analysis is to be carried out in accordance with methods laid down in a standard recognized by the Society.

## 6 Accident Limit States (*ALS*)

1 Accident design condition as described in **6.4.12(3), Part GF of the Rules** is to be complied with as applicable, depending on the fuel containment system concept.

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.

3 The load factors for *ALS* are to be taken as 1.0 for permanent loads, functional loads and environmental loads.

4 Loads mentioned in **6.4.9-3(3)(h) and 6.4.9-5, Part GF of the Rules** need not be combined with each other or with environmental loads, as defined in **6.4.9-4, Part GF of the Rules**.

5 Resistance factor  $\gamma_R$  is to, in general, be taken as 1.0.

6 Consequence class factors  $\gamma_C$  are to, in general, be taken as defined in **4-4**, but may be relaxed considering the nature of the accident scenario.

7 The characteristic resistance  $R_k$  is to, in general, be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

8 Additional relevant accident scenarios are to be determined based on a risk analysis.

## 7 Testing

Fuel containment systems designed according to this standard are to be tested to the same extent as described in **16.2, Part GF of the Rules**, as applicable depending on the fuel containment system concept.

## EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2017.
2. Notwithstanding the amendments to the Rules, the current requirements apply to ships other than ships that fall under the following:
  - (1) for which the building contract is placed on or after the effective date; 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 2017; or(Note) The term “*a similar stage of construction*” means the stage at which the construction identifiable with a specific ship begins and the assembly of that ship has commenced comprising at least 50 tonnes or 1%\* of the estimated mass of all structural material, whichever is the less.

\* For high speed craft, “1%” is to be read as “3%”.

  - (3) the delivery of which is on or after 1 January 2021.
3. Notwithstanding the provision of preceding 2., the amendments to the Rules apply to the ships that fall under the following:
  - (1) which convert to using low-flashpoint fuels on or after the effective date; or
  - (2) which, on or after the effective date, undertake to use low-flashpoint fuels different from those which it was originally approved to use before the effective date.

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# **GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS**

**Part GF**

**Ships Using Low-Flashpoint Fuels**

**GUIDANCE**

**2016 ESTABLISHMENT**

Notice No.83      27th December 2016

Resolved by Technical Committee on 27th July 2016

Notice No.83 27th December 2016

## AMENDMENT TO THE GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

“Guidance for the survey and construction of steel ships” has been partly amended as follows:

Part GF has been established as follows.

### **Part GF SHIPS USING LOW-FLASHPOINT FUELS**

#### **GF1 GENERAL**

##### **GF1.1 General**

##### **GF1.1.3 Approval of Systems and Equipment, etc.**

The wording “to be approved as specified separately by the Society” specified in **1.1.3-1, Part GF of the Rules** means that an approval is to be obtained in accordance with **Annexes 1 to 4**.

## **GF2    DEFINITIONS**

### **GF2.2   Definitions**

#### **GF2.2.1   Terms**

**1**    The wording “electrical equipment deemed appropriate by the Society” specified in **2.2.1-4, Part GF of the Rules** means the following **(1)** or **(2)**:

- (1)**   That having passed type tests for explosion-protected electrical equipment for each type in accordance with **1.2.1-4(4), Part H of the Rules** or that deemed unlikely to cause the ignition;  
or
- (2)**   That evaluated and certified/registered safe by the relevant authorities recognized by the Society.

**2**    In applying **2.2.1-11, Part GF of the Rules**, reference is to be made to *IEC 60092-502:1999*.

**3**    In applying **2.2.1-38, Part GF of the Rules**, reference is to be made to *IEC 60092-502:1999*.

## **GF4    GENERAL REQUIREMENTS**

### **GF4.3   Limitation of Explosion Consequences**

#### **GF4.3.1    General Requirements**

In applying **4.3.1, Part GF of the Rules**, double wall fuel pipes are not considered as potential sources of release.

## **GF5 SHIP DESIGN AND ARRANGEMENT**

### **GF5.7 Location and Protection of Fuel Piping**

#### **GF5.7.2 Piping**

The wording “electrical equipment rooms” specified in **5.7.2, Part GF of the Rules** includes auto-telephone exchange and air-conditioning duct spaces.



## GF6 FUEL CONTAINMENT SYSTEM

### GF6.3 General

#### GF6.3.1 General

**1** In applying **6.3.1-5, Part GF of the Rules**, means deemed necessary based on the specific design, including safety precautions against damage of piping connections, are to be provided as in addition to applying **6.3.1-9, Part GF of the Rules**.

**2** The wording “other sources of leakage” specified in **6.3.1-10, Part GF of the Rules** includes flange connections, valves, etc.

### GF6.4 Liquefied Gas Fuel Containment

#### GF6.4.8 Thermal Insulation

For the purpose of the requirements in **6.4.8, Part GF of the Rules**, the insulation of vacuum insulated tanks is to be as deemed appropriate by the Society.

#### GF6.4.13 Materials and Construction

**1** For the purpose of the requirements in **6.4.13-3(2), Part GF of the Rules**, tests and inspection specified in the following **(1)** and **(2)** are to be carried out.

**(1)** The insulation materials are to be approved in accordance with the **Annex 1 “Guidance for Equipment and Fittings of Ships Using Low-flashpoint Fuels”**. In the above, tests and inspection are to be conducted according to the procedures on the manufacture, storage, handling and product quality control established by the manufacturer.

**(2)** The inspection for insulation work is to include the following items of tests and inspections **(a)** to **(c)**:

**(a)** Insulation procedure test

For insulation system and insulation procedure without previous records, tests are to be conducted in accordance with the test plan approved by the Society. The test may be conducted at the manufacturer of insulation materials or shipyard as necessary.

**(b)** Insulation production test

In accordance with the test plan approved by the Society in advance, tests are to be conducted to verify the work control, working environment control and product quality control during insulation procedure.

**(c)** Completion inspection

After the insulation work is completed, inspection is to be conducted for dimensions, shape, appearance, etc. in accordance with the procedures already approved by the Society, and in addition, the insulation performance is also to be verified in the test specified in **16.5.1-6, Part GF of the Rules**.

**2** For the purpose of the requirements in **6.4.13-3(2), Part GF of the Rules**, the properties of insulation materials are, in general, to be verified by the tests given in **Table GF6.4.13**.

**3** In addition to complying with the requirements in the preceding **-2**, property verification test may be requested by the Society depending on the insulation system.

**4** If the material, which has been approved according to the **Annex 1 “Guidance for Equipment and Fittings of Ships Using Low-flashpoint Fuels”**, satisfies the performance requirements and such performance is considered to serve the purpose, the tests referred to in the preceding **-2** may be omitted.

**5** For insulation materials to which the requirements in the preceding -2 to -4 do not apply, the following requirements (1) and (2) are to be complied with:

- (1) For insulation materials used for supports of independent tanks, the requirements given in the column of membrane tank in **Table GF6.4.13** apply.
- (2) For insulation materials provided in cargo tanks to which no provision of insulation is required according to the requirements in **6.4.8, Part GF of the Rules**, data on the necessary properties of those specified in **6.4.13-3(2), Part GF of the Rules** depending on the insulation system is to be submitted to the Society.

**Table GF6.4.13 Properties of Insulation Material for Cargo Tank Types**

No.	Ensuring items	Membrane Tank	Type A/B independent tank	Type C independent tank	Note
1	Compatibility with the cargo	○ <sup>1)</sup>	○ <sup>1)</sup>		
2	Solubility in the cargo	○ <sup>1)</sup>	○ <sup>1)</sup>		
3	Absorption of the cargo	○ <sup>1)</sup>	○ <sup>1)</sup>		
4	Shrinkage	○ <sup>1)</sup>	○ <sup>1)</sup>		
5	Ageing	○	○ <sup>1)</sup>	□	
6	Closed cell content	△	△	△	applied only to closed cell material
7	Density	○	○	○	
8	Mechanical properties	Bending strength	○	○	
		Compress strength	○		
		Tensile strength	○	○	
		Shearing strength	○		
9	Thermal expansion	○	○ <sup>2)</sup>	○ <sup>2)</sup>	
10	Abrasion	○			
11	Cohesion	△	△ <sup>1)</sup>	□	applied to cohered material
12	Thermal conductivity	○	○	○	
13	Resistance to vibration	△	△ <sup>1)</sup>		refer to <b>6.4.13-3(7), Part GF of the Rules</b>
14	Resistance to fire and flame spread	○	○	○	
15	Resistance to fatigue failure	○			
16	Resistance to crack propagation	△			

Remarks:

○: Items to be verified through verification test for properties.

△: Items to be verified through verification test where deemed necessary depending on the insulation material.

□: Items for which preparation of data on the properties is desirable.

Notes:

1) Necessary when the insulation material acts as spray shield specified in the requirements in **6.4.5-1, Part GF of the Rules**. In other cases, data on the properties is to be prepared.

2) Not generally required for cargo tanks where the design temperature exceeds -10°C.

## **GF6.6 CNG Fuel Containment Systems**

### **GF6.6.3 Depressurization of Tanks**

The means “to depressurize the tank” specified in **6.6.3, Part GF of the Rules** means use of vent as an example.

## GF6.7 Pressure Relief Systems

### GF6.7.2 Pressure Relief Systems for Liquefied Gas Fuel Tanks

In applying **6.7.2-3, Part GF of the Rules**, sizing of pressure relief devices is to be in accordance with the following **(1)** to **(4)**:

- (1) The combined relieving capacity of the pressure relief devices for interbarrier spaces surrounding type *A* independent tanks where the insulation is fitted to the tanks may be determined by the following formula:

$$Q_{sa} = 3.4 A_c \frac{\rho}{\rho_v} \sqrt{h} \quad (m^3/s)$$

where:

$Q_{sa}$  = minimum required discharge rate of air at standard conditions of 273 K and 1.013 bar

$A_c$  = design crack opening area ( $m^2$ )

$$A_c = \frac{\pi}{4} \delta l \quad (m^2)$$

$\delta$  = max crack opening width ( $m$ )

$$\delta = 0.2t \quad (m)$$

$t$  = thickness ( $m$ ) of tank bottom plating

$l$  = design crack length ( $m$ ) equal to the diagonal of the largest plate panel of the tank bottom.

$h$  = max liquid height ( $m$ ) above tank bottom plus 10 MARVS

$\rho$  = density of product liquid phase ( $kg/m^3$ ) at the set pressure of the interbarrier space relief device

$\rho_v$  = density of product vapour phase ( $kg/m^3$ ) at the set pressure of the interbarrier space relief device and a temperature of 273 K

MARVS = max allowable relief valve setting (*bar*) of the fuel tank.

- (2) The relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type *B* tanks may be determined on the basis of the method given in **(1)** above, however, the leakage rate is to be determined in accordance with **4.7.2, Part N of the Rules**.
- (3) The relieving capacity of pressure relief devices for interbarrier spaces of membrane and semimembrane tanks is to be evaluated on the basis of specific membrane/semi-membrane tank design.
- (4) The relieving capacity of pressure relief devices for interbarrier spaces adjacent to integral type tanks may, if applicable, be determined as for type *A* independent tanks.

## GF6.14 Inert Gas Production and Storage on Board

### GF6.14.1 Inert Gas Production and Storage on Board

**1** For the purpose of the requirements in **6.14.1-1, Part GF of the Rules**, inert gas systems are to comply with the following **(1)** through **(4)**.

- (1) Materials used in inert gas systems are to be suitable for their intended purpose.
- (2) Each system component of the inert gas systems using oil fired inert gas generators, inert gas storage systems and liquid nitrogen storage tanks is to be approved in accordance with the **Annex 1 “GUIDANCE FOR SURVEY AND CONSTRUCTION OF EQUIPMENT AND FITTINGS OF SHIPS USING LOWFLASHPOINT FUELS”**. Where the oil fired inert gas

generator is fitted for the purposes of **6.11** and **6.12 of the Rules**, the requirements of **8.2.2-4, 8.2.2-8, 8.2.2-9, 8.2.2-10, 8.2.2-12** and **8.2.3-2** of the **Annex 1** may not apply.

- (3) Inert gas systems using nitrogen generators are to comply with the following requirements in (a).
- (a) **35.2.2-2(2), 35.2.2-2(4), 35.2.2-4(2), 35.2.2-4(3), 35.2.2-4(5)(a)** (except (a)iii) through v)), **35.2.2-4(5)(d), 35.2.4(1)(c), 35.2.4(1)(d), 35.2.4(1)(f), 35.2.4(1)(g), 35.2.4(1)(h), 35.2.4(1)(i), 35.2.4(1)(j), 35.2.4(2), Part R of the Rules** and the requirements of **8.2.2-11** in the **Annex 1 “GUIDANCE FOR SURVEY AND CONSTRUCTION OF EQUIPMENT AND FITTINGS OF SHIPS USING LOW-FLASHPOINT FUELS”** are to apply.
- (4) Inert gas systems using boiler flue gases are to comply with the requirements of **Chapter 35, Part R of the Rules** under the following conditions.
- (a) The requirements of **8.2.2-11** in the **Annex 1 “GUIDANCE FOR SURVEY AND CONSTRUCTION OF EQUIPMENT AND FITTINGS FOR SHIPS USING LOW-FLASHPOINT FUELS”** may apply in place of the requirements of **35.2.3(1)(b)i** and **ii), Part R of the Rules**.
- (b) The requirements of **6.13.1, Part GF of the Rules** may apply in place of the requirements of **35.2.2-3(1)(a)** through (i), **Part R of the Rules**.
- (c) The requirements of **35.2.2-4(5)(c)** and **35.2.3(2)(b)vii), Part R of the Rules** may not apply.
- (d) Where the systems are fitted for the purposes of **6.11** and **6.12, Part GF of the Rules**, the requirements of **4.5.3-4(2), 4.5.6-3, 11.6.3-4, 35.2.2-1(2)(d), 35.2.2-2(4), 35.2.2-3(2)** (except (d)), **35.2.3(1)(c)i** and **35.2.3(1)(d)i), Part R of the Rules** may not apply, in addition to (1) to (3) above.

## GF7 MATERIAL AND GENERAL PIPE DESIGN

### GF7.3 General Pipe Design

#### GF7.3.1 General

The wording “standard recognized by the Society” specified in 7.3.1-1, **Part GF of the Rules** means *EN ISO 14726:2008*.

#### GF7.3.2 Wall Thickness

**1** In applying 7.3.2-1, **Part GF of the Rules**, the negative manufacturing dimensional deviation in pipe thickness is, unless otherwise specified, to be in accordance with the requirements in 4.1.7, 4.2.7, 4.3.7, 4.4.7 and 4.5.7, **Part K of the Rules**.

**2** In applying 7.3.2-1, **Part GF of the Rules**, the corrosion allowance is to be in accordance with the following (1) and (2):

- (1) For methane, propane, butane, butadiene and propylene, the corrosion allowance is to be 0.3 mm for carbon-Mn steel and 0 mm for stainless steel and aluminium alloys. Where effective corrosion controls are taken for the interior of carbon-Mn steel pipes, the corrosion allowance may be 0.15 mm; and
- (2) In addition to the (1) above, for carbon-Mn steel pipes arranged on open decks without any effective external corrosion-control means, 1.2 mm is to be added to the required corrosion allowance.

**3** In applying 7.3.2-2, **Part GF of the Rules**, the value given in column F of **Table D12.6(2), Part D of the Rules** for carbon-Mn steel and the value corresponding to Schedule 10S for stainless steel are to be used. However, for steel pipes provided with effective corrosion control or not arranged under corrosive environment, the value may be reduced to the extent acceptable to the Society with a limitation of 1mm. Furthermore, the value for pipes in fuel tanks and pipes having open ends may also be reduced to the extent acceptable to the Society.

#### GF7.3.3 Design Condition

In applying 7.3.3-1, **Part GF of the Rules**, the following (1) and (2) are applied.

- (1) Lower values of ambient temperature may be accepted by the Society 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 (See “*SIGTTO :Application of Amendments to Gas Carrier Codes oncerning type C Tank Loading Limits*”).

#### GF7.3.6 Piping Fabrication and Joining Details

**1** The wording “standard recognized by the Society” specified in 7.3.6-1, **Part GF of the Rules** means *JIS* or other equivalent standards related to types and manufacturing of flanges, valves and other fittings.

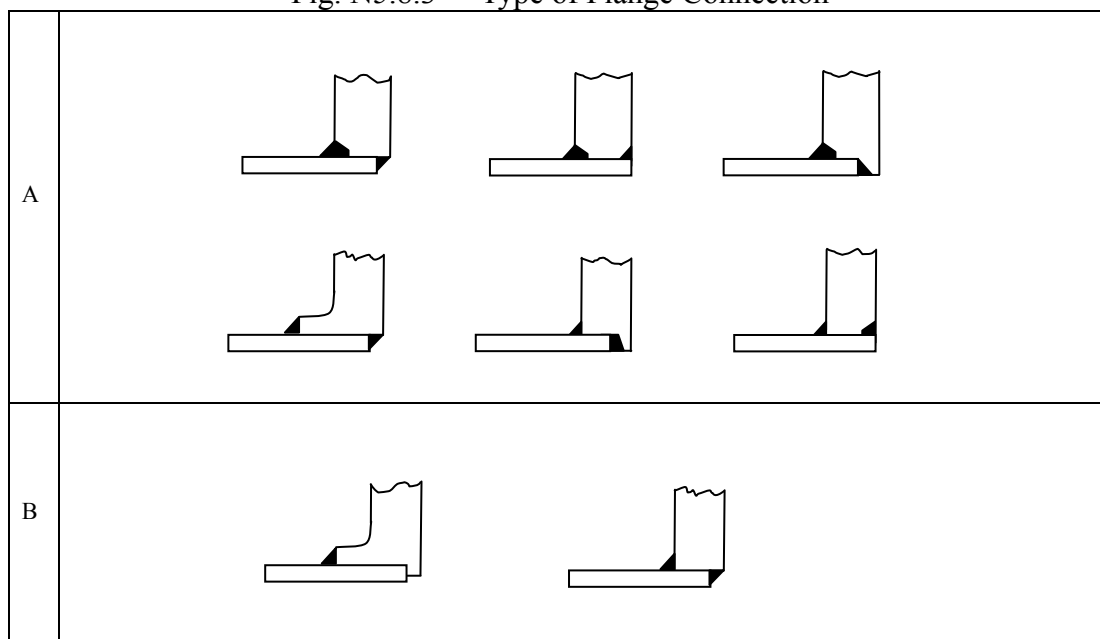
**2** The wording “standards recognized by the Society” specified in 7.3.6-4(1)(b), **Part GF of the Rules** means *JIS B 2316* or *JIS F 7810* or other equivalent standards.

**3** The wording “standards recognized by the Society” specified in 7.3.6-4(1)(c), **Part GF of the Rules** means *JIS B 0203* or other equivalent standards.

**4** In applying the requirements of 7.3.6-4(2), **Part GF of the Rules**, flanges of flange connections are to conform to *JIS* or other standards deemed appropriate by the Society for their type, manufacturing and testing. The term “slip-on flanges” here refers to the type described in **A** of

**Fig. GF7.3.6-1**, and “socket welded flanges” refers to the type described in **B** of **Fig. GF7.3.6-1**.

**Fig. N5.8.3 Type of Flange Connection**



## GF7.4 Regulations for Materials

### GF7.4.1 Metallic Materials

**1** For the purpose of the requirements in **Table GF7.1, Part GF of the Rules**, the following requirements **(1)** to **(4)** are to be complied with:

- (1) The use of the longitudinally or spirally welded pipes given in the Note 1 of the Table is to be in accordance with the relevant requirements in **Chapter 4, Part K of the Rules**.
- (2) Fittings of Type *C* independent tanks and process pressure vessels with the design pressure not exceeding  $3\text{ MPa}$  and design temperature of  $0^\circ\text{C}$  or more and nominal diameter less than  $100A$ .
- (3) The controlled rolling as a substitution for normalizing may be of the temperature controlled rolling or Thermo-Mechanical Controlled Processing (*TMCP*).
- (4) For materials with the thickness of greater than  $40\text{ mm}$  and not more than  $50\text{ mm}$ , the impact test is to be carried out at the temperature of  $-30^\circ\text{C}$ .

**2** The controlled rolling as a substitution for normalizing or tempering and quenching given in Note 4 of **Table GF7.2, Part GF of the Rules** may be of *TMCP*.

**3** For the purpose of the requirements in **Table GF7.3, Part GF of the Rules**, the following requirements **(1)** to **(4)** are to be complied with:

- (1) For the purpose of the requirements in Note 2 of the Table, aluminium alloy of 5083, austenitic stainless steel,  $36\%\text{Ni}$  steel and  $9\%\text{Ni}$  steel may be used at the design temperature up to  $-196^\circ\text{C}$ .
- (2) For the purpose of the requirements in Note 4 of the table,  $9\%\text{Ni}$  steel greater than  $25\text{ mm}$  and up to  $40\text{ mm}$  in thickness is to be in accordance with the requirements for  $9\%\text{Ni}$  steel not greater than  $25\text{ mm}$ .
- (3) For the purpose of the requirements in Note 5 of the Table, the chemical composition limit of a material, if the material specified in **Part K of the Rules**, is to be in accordance with the relevant requirements in **Part K**.
- (4) For the purpose of the requirements in Note 9 of the Table, the omission of the impact test

given in Note 9 of this Table may generally be accepted for the austenitic stainless steel of the type referred to in the Table.

**4** For the purpose of the requirements in **Table GF7.4, Part GF of the Rules**, the following requirements **(1)** through **(5)** are to be complied with:

- (1) The use of vertically or spirally welded pipes given in Note 1 of the Table is to be in accordance with the requirements in the preceding **-1(1)**.
- (2) The requirements for forgings and castings given in Note 2 of the Table are to be in accordance with the relevant requirements in the **Part K**, if specified.
- (3) For the design temperature given in Note 3 of the Table lower than -165°C, the provision in the preceding **-3(1)** are to apply.
- (4) The chemical composition limit given in Note 5 of the Table is to be in accordance with the requirements in the preceding **-3(3)**.
- (5) The omission of the impact test given in Note 8 of this Table are to be in accordance with the requirements in the preceding **-3(4)**.

**5** For the purpose of the requirements in **7.4.1-1(6), Part GF of the Rules**, the specifications of a certain type of material, if specified in **Part K of the Rules**, is to be in accordance with the relevant requirements in **Part K of the Rules**.

## **GF9 FUEL SUPPLY TO CONSUMERS**

### **GF9.4 Safety Functions of Gas Supply Systems**

#### **GF9.4.1 Location of Valves**

The wording “normal operation” specified in **9.4.1, Part GF of the Rules** means when gas is supplied to consumers and during bunkering operations.

#### **GF9.4.10 Protection against Rupture**

With regard to the wording “shut off” specified in **9.4.10, Part GF of the Rules**, shutdown is to be time delayed to prevent shutdown due to transient load variations

### **GF9.5 Fuel Distribution outside of Machinery Spaces**

#### **GF9.5.1 Fuel Pipes**

In cases where double wall piping with vacuum used as secondary enclosure is adopted as “other solutions” specified in **9.5.1, Part GF of the Rules**, appropriate means capable of detecting loss of vacuum are to be provided, in addition to applying **2.2.1-37, Part GF of the Rules**.

### **GF9.6 Fuel Supply to Consumers in Gas-safe Machinery Spaces**

#### **GF9.6.1 Fuel Piping**

In cases where double wall piping with vacuum used as secondary enclosure is adopted as “other solutions” specified in **9.6.1(3), Part GF of the Rules**, appropriate means capable of detecting loss of vacuum are to be provided, in addition to applying **2.2.1-37, Part GF of the Rules**.

#### **GF9.6.2 Connecting**

In applying **9.6.2, Part GF of the Rules**, 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.



## **GF10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS**

### **GF10.2 Functional Requirements**

#### **GF10.2.2 Additional Requirements**

In applying **10.2.2-2, Part GF of the Rules**, air inlet manifolds and scavenge spaces which are not capable of withstanding a pressure 7 times the design pressure are to be provided with pressure relief systems.

### **GF10.3 Internal Combustion Engines of Piston Type**

#### **GF10.3.1 General**

An example of means provided to “monitor and detect poor combustion or misfiring” specified in **10.3.1-6, Part GF of the Rules** is sensors fitted to monitor the exhaust gas temperature and the status of knocking.

## **GF12 EXPLOSION PREVENTION**

### **GF12.4 Hazardous Areas**

#### **GF12.4.2 Classification of Hazardous Areas**

In applying **12.4.2, Part GF of the Rules**, applicable requirements of **Chapter 4, Part H of the Rules** are to be complied with.

### **GF12.5 Hazardous Area Zones**

#### **GF12.5.2 Hazardous Area Zone 1**

**1** Measuring instruments and electrical equipment are to be capable of being used in the hazardous area zone 1.

**2** Fuel storage hold spaces for type *C* tanks are normally not considered as hazardous area zone 1.

**3** The wording “areas on open deck, or semi-enclosed spaces on deck, within 3 *metre* of any fuel tank outlet, gas or vapour outlet” specified in **12.5.2(3), Part GF of the Rules** means, for example, all areas within 3 *metre* of fuel tank hatches, ullage openings or sounding pipes for fuel tanks located on open deck and gas vapour outlets.

#### **GF12.5.3 Hazardous Area Zone 2**

Measuring instruments and electrical equipment are to be capable of being used in the hazardous area zone 2.

## **GF13 VENTILATION**

### **GF13.3 General Requirements**

#### **GF13.3.1 Ventilation of Hazardous Areas**

The wording “all temperatures and environmental conditions the ship will be operating in” specified in **13.3.1, Part GF of the Rules** means those specified in **1.3.1, Part D of the Rules** and **1.1.7, Part H of the Rules**.

#### **GF13.3.3 Design of Ventilation Fans Serving Spaces Containing Gas Sources**

In applying **13.3.3, Part GF of the Rules**, protection screens of not more than 13 *mm* square mesh are to be fitted in the ventilation openings on the open deck of the ducts in which fans are fitted.

#### **GF13.3.9 Non-hazardous Areas with Entry Openings to a Hazardous Area**

The wording “standard recognized by the Society” specified in **13.3.9(2)(b), Part GF of the Rules** means those specified in table 5 of *IEC 60092-502*.

### **GF13.5 Machinery Spaces**

#### **GF13.5.3 Redundancy of Ventilation Systems**

The wording “standard recognized by the Society” specified in **13.5.3, Part GF of the Rules** means *IEC 60079-10-1*.

## **GF14 ELECTRICAL INSTALLATIONS**

### **GF14.3 General**

#### **GF14.3.4 Failure Modes and Effects Analysis**

The wording “standard recognized by the Society” specified in **14.3.4, Part GF of the Rules** means *IEC 60812*.

## **GF15 CONTROL, MONITORING AND SAFETY SYSTEMS**

### **GF15.2 Functional Requirements**

#### **GF15.2.2 Additional Requirements**

The wording “Failure of valve control actuating medium” specified in **Table GF15.1, Part GF of the Rules** includes failures of valve control actuating medium control systems.

### **GF15.6 Gas Compressor Monitoring**

#### **GF15.6.1 Gas Compressors**

In applying **15.6.1, Part GF of the Rules** for compressors for bunkering, it is to be so arranged that the audible and visual alarms specified in **15.6.1, Part GF of the Rules** will be given also in the bunkering control location in cases of gas.

#### **GF15.6.2 Shaft Glands and Bearings**

In applying **15.6.2, Part GF of the Rules** compressors for bunkering, the temperature monitoring for the bulkhead shaft glands and bearings is to be so arranged that the audible and visual alarms specified in **15.6.2, Part GF of the Rules** will be given also in the bunkering control location.

### **GF15.8 Gas Engine Monitoring**

#### **GF15.8.5 Design, Installation and Test for Gas Detection Equipment**

The wording “standard recognized by the Society” specified in **15.8.5, Part GF of the Rules** means *IEC 60079-29-1*.

### **GF15.10 Ventilation**

#### **GF15.10.1 Alarms**

In applying **15.10.1, Part GF of the Rules**, means for measuring ventilation flow rate, means capable of detecting mechanical ventilation system stop or other equivalent means are to be provided.

## **GF16 MANUFACTURE, WORKMANSHIP AND TESTING**

### **GF16.1 General**

#### **GF16.1.1 General**

For the purpose of the requirements in **16.1.1-2, Part GF of the Rules**, when post-weld heat treatment is carried out, the properties of the base material are to be in accordance with the requirements given in **Table GF7.1 to Table GF7.4, Part GF of the Rules** in the heat treated condition or equivalent condition whether such post-weld heat treatment is regarded in **16.6.2, Part GF of the Rules** or not. Welding procedure qualification tests and production weld tests specified in the requirements in **16.2, Part GF of the Rules** are to satisfy the requirements in **16.3.3-5** and **16.3.5, Part GF of the Rules** in the heat treated condition.

### **GF16.2 General Test Regulations and Specifications**

#### **GF16.2.1 Tensile Test**

For the purpose of the requirements in **16.2.1-2, Part GF of the Rules**, the required values of tensile strength, yield stress and elongation of a material are to be in accordance with the requirements in **Part K of the Rules** applicable to the material.

#### **GF16.2.2 Toughness Test**

The wording “To be in accordance with Recognized Standard” referred to in the requirements given **16.2.2-1, Part GF of the Rules** means to refer to **note (6) of Table K4.28**.

#### **GF16.2.4 Section Observation and Other Testing**

The wording “To be carried out as deemed appropriate by the Society” referred to in the requirements given **16.2.4, Part GF of the Rules** means to refer to, for welding procedure tests of the cargo tanks and process pressure vessels, **GF16.3.3-1(2)**.

### **GF16.3 Welding of Metallic Materials and Non-destructive Testing for the Fuel Containment System**

#### **GF16.3.1 General**

**1** The requirements in **16.3, Part GF of the Rules** apply to independent tanks, process pressure vessels and piping. The requirements on membrane tanks, are to the satisfaction of the Society depending on the structural type of the tank.

**2** For the purpose of the requirements in **16.3, Part GF of the Rules**, the following requirements **(1)** and **(2)** are to be complied with.

- (1)** The impact test for welded joint may generally be omitted for austenitic stainless steels of types given in **Table GF7.3** and **Table GF7.4, Part GF of the Rules**.
- (2)** The impact test for welded joint may generally be omitted for aluminum alloys of type 5083. In addition, additional tests may be required to verify the toughness of the material for aluminum alloys other than type 5083.

#### **GF16.3.3 Welding Procedure Tests for Fuel Tanks and Process Pressure Vessels**

**1** For the purpose of the requirements in **16.3.3-4, Part GF of the Rules** the following requirements **(1)** and **(2)** are to be complied with:

- (1) Longitudinal bend tests which are required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels, as specified in **16.3.3-4(3), Part GF of the Rules**, are to be in accordance with the requirements in **4.2, Part M of the Rules**.
- (2) For the purpose of the requirements in **16.3.3-4, Part GF of the Rules**, for type *C* independent tanks and process pressure vessels, macroscopic and microscopic examinations and hardness tests are to be carried out according to the requirements in **Chapter 11, Part D of the Rules**. For other independent tanks, macroscopic examinations are to be carried out according to the requirements in **Chapter 4, Part M of the Rules**.
- 2** For the purpose of the requirements in **16.3.3-5, Part GF of the Rules**, the welding procedure qualification tests are also to be complied with the relevant requirements in **Chapter 4, Part M** and **Chapter 11, Part D of the Rules**.
- 3** For the purpose of the requirements in **16.3.3-5(1), Part GF of the Rules**, the transverse tensile strength of weld metal which has lower tensile strength than that of the parent metal is to be complied with the requirements in **4.2.5, Part M of the Rules**.
- 4** For the purpose of the requirements in **16.3.3-5(2), Part GF of the Rules**, bend tests are also to be complied with the requirements in **4.2.6, Part M of the Rules**.
- 5** For the purpose of the requirements in **16.3.3-5(3), Part GF of the Rules**, when the design temperature of a material falls under the higher temperature range than the specified one for the material in **Table GF7.3** and **Table GF7.4, Part GF of the Rules**, the impact test temperature given in **Table GF7.1** to **Table GF7.4, Part GF of the Rules** correspondingly to the design temperature may be used instead of the impact test temperature depending on the material. For example, in the case of 2.25%Ni steel pipes used at the design temperature of -45°C, the impact test temperature may be -50°C, while in the case of 3.5%Ni steel plates used at the design temperature of -61°C, the impact test temperature may be -70°C.

#### **GF16.3.4 Welding Procedure Tests for Piping**

For the purpose of the requirements in **16.3.4, Part GF of the Rules**, welding procedure qualification tests for pipes are also to be in accordance with the relevant requirements in **Chapter 11, Part D** and **Chapter 4, Part M of the Rules** are to be complied with.

#### **GF16.3.5 Production Weld Tests**

**1** Production weld tests are to be in accordance with the requirements specified in **16.3.5, Part GF** and **Chapter 11, Part D of the Rules** and are also to comply with the following requirements:

##### **(1) Application**

When welding is made for independent tanks of ships carrying liquefied gases in bulk, the production weld tests are to be carried out for each position of welding in accordance with the following requirements, in addition to the welding procedure qualification tests specified in **Part M of the Rules**.

##### **(a) Type A independent tanks**

The production weld test is to be carried out on at least one test sample for every 50m of welding length of butt joints of principal structural members. However, consideration may be given for reduction of the number of test sample or omission of the production weld test taking into account the past records and the actual state of quality control system of the manufacturer.

##### **(b) Type B independent tanks**

The production weld tests are to be carried out on at least one test sample for every 50m of welding length of butt joints of principal structural members. However, the number of test sample may be reduced to one test sample for every 100m of welding length taking into account the past records and the actual state of quality control system of the manufacturer. In this case, however, at least one or more test specimens are to be selected for one tank.

(c) Type *C* independent tanks

The production weld tests are to be carried out on at least one test sample for every 30m of welding length of butt joints of principal structural members. However, the number of test sample may be reduced to one test sample for every 50m of welding length taking into account the past records and the actual state of quality control system of the manufacturer.

(2) Test procedure

(a) The production weld tests are to be carried out for every welding length specified in the above (1) for welded joints made under the same welding procedure, welding position and welding conditions.

(b) Test sample are, in principle, to be located on the same line as the welded joints of the body and to be welded at the same time of welding of the body.

(3) Kind of test

Kinds of the test are to be as given in **Table GF16.3.5-1**.

(4) Test assemblies

The shape and size of test assemblies are to be as shown in **Fig. GF16.3.5-1**. In cases of Type *A* and Type *B* independent tanks, tensile test may not be required.

(5) Test specimens

(a) The shape and size of tensile test specimens are to be of the *U2A* or *U2B* test specimen specified in **Table M3.1, Part M of the Rules**.

(b) The shape and size of bend test specimens are to be of the *UB-1*, *UB-2* and *UB-3* test specimens specified in **Table M3.2, Part M of the Rules**. For test specimens with a thickness exceeding 20mm, side bend test specimens are to be substituted for face bend and root bend test specimens.

(c) Impact test specimens are to be the *U4* test specimen specified in **Table K2.5, Part K of the Rules**. In the impact test, one set of test specimens comprising three pieces are to be taken from every test assembly.

The test specimens are to be taken alternately from the position *A* and from a position among *B* through *E* where the lowest value is recorded in the welding procedure qualification test, shows in **Fig. M4.4, Part M of the Rules**. This means that one set of three test specimens are taken from a test assembly at the position *A*, thence other set of three test specimens are taken in the subsequent test assembly from the position among *B* through *E* where the lowest value is recorded, and this procedure is repeated.

(6) Tensile test

The tensile strength of weld metal is to be more than the specified value of the base metal. However, the tensile strength of weld metal which has lower tensile strength than that of the parent metal is to be complied with the requirements in **4.2.5, Part M of the Rules**.

(7) Bend test

(a) The bend test specimen is to be bent up to an angle of 180 *degrees* by a test jig with an inner radius of double the thickness of the test specimen.

(b) The results of the bend test are to be as free from cracks exceeding 3mm in length in any direction on the outer bent surface and from other significant defects.

(8) Impact test

The specified value for the impact test are as given in **Table M4.8, Part M of the Rules**.

**2** For the purpose of the requirements in **16.3.5-1, Part GF of the Rules**, the number of test specimens for production weld tests of secondary barriers may be reduced to the extent as deemed appropriate by the Society considering the experience of same welding procedures in past, workmanship and quality control. In general, intervals of production tests for secondary barriers may be approximately 200 m of butt weld joints and the tests are to be representative of each welding position.



**3** For the purpose of the requirements in **16.3.5-5, Part GF of the Rules**, production weld tests for membrane tanks are left to the discretion of the Society depending on the construction system of the tank.

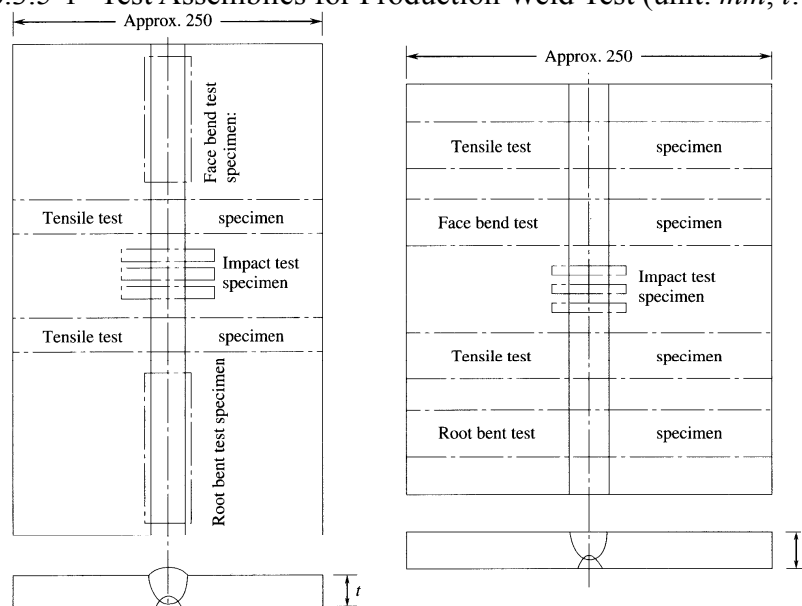
Table GF16.3.5-1 Kind of Tests

Material	Kind of test
9% Ni steel	Tensile test, bend test and impact test
Austenitic stainless steel	Tensile test, bend test
Aluminium alloy <sup>(1)</sup>	Tensile test, bend test
Steel for low temperature service (excluding 9% Ni steel)	Tensile test, bend test and impact test

Note:

- (1) For aluminium alloys other than type 5083, additional tests may be required to verify the toughness of the material.

Fig. GF16.3.5-1 Test Assemblies for Production Weld Test (unit: mm, *t*: thickness)



(a) For 9% Ni steel

(b) For materials other than (a)

### GF16.3.6 Non-destructive Testing

**1** The following requirements (1) through (4) are to apply as the testing procedures and acceptance criteria for the non-destructive tests referred to in the requirements in **16.3.6-1, Part GF of the Rules**:

- (1) Radiographic testing is to comply with the requirements specified in **11.4.5, Part D of the Rules**. The requirements specified in **D11.4.5-2(2)**, however, are not to be applied.
- (2) For ultrasonic tests, the requirements in **11.4.6-2, Part D of the Rules** apply correspondingly.
- (3) For magnetic particle test, the requirements in **11.4.6-2, Part D of the Rules** apply correspondingly.
- (4) For dye penetrant tests, the requirements in **11.4.6-2, Part D of the Rules** apply correspondingly.

**2** Where ultrasonic tests are performed as a substitution for radiographic tests according to the requirements in **16.3.6-1, Part GF of the Rules**, at least 10% of the whole testing objects are to be

subjected to radiographic tests.

**3** For the non-destructive tests specified in the requirements in **16.3.6-2, Part GF of the Rules** for the remaining welds of tank plates of type *A* and *B* independent tanks other than butt welds, fillet welds of highly stressed parts of main structural members of fuel tanks are to be examined magnetic particle or dye penetrant tests given in **-1** above. Butt welds of highly stressed parts of main structural members such as face plates of girders are to be subjected to radiographic test given in **-1** above.

**4** For the purpose of the requirements in **16.3.6-4(2), Part GF of the Rules**, the ultrasonic testing is to be conducted in the following cases **(1)** and **(2)**:

- (1) In case where defect detection by radiographic testing fails and ultrasonic testing is considered additionally necessary.
- (2) In case where ultrasonic testing is considered necessary for the quality control of essential structural members.

**5** For the purpose of the requirements in **16.3.6-7, Part GF of the Rules**, radiographic tests of secondary barriers where the hull structure acts as the secondary barrier are to be carried out for butt welded joints of the double bottom tank top platings and bulkhead platings in addition to the objects of inspections specified in **Annex M1.4.2-3(1) “GUIDANCE FOR NON-DESTRUCTIVE INSPECTIONS ON INTERNAL IMPERFECTIONS OF THE WELDED JOINTS OF HULL CONSTRUCTIONS”**. Acceptance criteria of radiographic tests are to be in accordance with the requirements specified in **Annex M1.4.2-3(1)**.

## **GF16.6 Welding, Post-weld Heat Treatment and Non-destructive Testing**

### **GF16.6.3 Non-destructive Testing**

The phrase “when such butt welded joints of piping sections are made by automatic welding procedures approved by the Society” specified in **16.6.3, Part GF of the Rules** means the case where the manufacturers who carry out welding are regarded as having the ability to carry out good-quality welding at all times and keep well-documented quality assurance procedures and records so that such good-quality welding can be carried out at all times.

## **GF16.7 Testing**

### **GF16.7.1 Type Testing of Piping Components**

The wording “standards recognized by the Society” specified in **16.7.1(4), Part GF of the Rules** means *ISO 19921:2005* and *ISO 19922:2005*.

## **GF17 OPERATING REQUIREMENTS**

### **GF17.5 Operating Requirements**

#### **GF17.5.3 Inspection and Maintenance of Electrical Installations**

The wording “standard recognized by the Society” specified in **17.5.3, Part GF of the Rules** means *IEC 60079-17*.

#### **GF17.5.4 Bunkering Operation**

**1** With regard to the wording “ship shore link (*SSL*) or equivalent means to a bunkering source provided for automatic *ESD* communications” specified in **17.5.4-3(4), Part GF of the Rules**, reference is to be made to *ISO 28460*.

**2** The wording “standards recognized by the Society” specified in **17.5.4-4, Part GF of the Rules** means *API RP 2003* and “*ISGOTT: International Safety Guide for Oil Tankers and Terminals*”.

#### **GF17.5.5 Enclosed Space Entry**

In applying **17.5.5-1, Part GF of the Rules**, reference is to be made to *IMO Assembly Resolution A.1050(27)*.

# **Annex 1      GUIDANCE FOR EQUIPMENT AND FITTINGS OF SHIPS USING LOW-FLASHPOINT FUELS**

## **Chapter 1      GENERAL**

### **1.1      Application**

**1** This annex specifies the technical requirements applicable to the fuelhandling equipment and fittings used in ships using low-flashpoint fuels (hereinafter referred to as “equipment, etc.” in this chapter) in accordance with relevant requirements in **Part GF of the Rules** and **Part GF of the Guidance**.

**2** For equipment, etc. manufactured in accordance with the requirements of rules or standards which are recognized to be equivalent to those contained in this annex and certified by an organization approved by the Society, some or all of the requirements in this annex need not be applied in cases where deemed appropriate by the Society.

### **1.2      Submission of Plans and Documents**

In accordance with the requirements in **2.1.2-1(5)**, **2.1.3-1(9)** and **2.1.3-2, Part B of the Rules**, the following plans and documents related to equipment, etc. as well as those specified in the following chapters of this annex and thereafter where appropriate are to be submitted to the Society.

**(1) Plans and documents for approval**

- (a) List of particulars
- (b) Details of structural parts
- (c) Material specifications of structural parts
- (d) Details of welding procedures for structural parts (including tests and inspections)
- (e) Local piping diagrams (various piping diagrams specifying the materials, sizes and working pressures of the pipes)
- (f) Diagrams of control systems (including monitoring, safety and alarm systems)
- (g) Other plans and documents deemed necessary by the Society depending upon the type of the equipment, etc.

**(2) Other plans and documents for reference**

- (a) Outline plans
- (b) Sectional assembly plans
- (c) Installation procedures
- (d) Instruction manuals
- (e) Strength calculation sheets for structural parts (thermal stress calculations are to be included where deemed necessary)
- (f) List of spare parts
- (g) Other plans and documents deemed necessary by the Society depending upon the type of equipment, etc.

### **1.3      Tests**

**1** For tests of equipment, etc., relevant requirements in **the Rules** and **the Guidance** apply. In addition, the tests specified in the following chapters of this annex are to be conducted depending upon the type of equipment, etc.

**2** In addition to the tests specified in **-1** above, more detailed tests for representative product

types may be requested by the Society taking into account the service conditions, construction and service records of the equipment, etc.

**3** The tests specified in **-1** and **-2** above are to be conducted at manufacturing plants. At the request of the manufacturer, however, parts or all of these tests may be conducted after installation on board ship in cases where deemed appropriate by the Society.

## Chapter 2 FUEL VAPOUR COMPRESSORS

### 2.1 General

#### 2.1.1 Application

1 The requirements in this chapter apply to the displacement type or centrifugal type gas compressors used for low-flashpoint fuel in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

2 Steam turbines, gas turbines, electric motors and their respective power transmission systems used for driving gas compressors are to comply with relevant requirements in **Part D** and **Part H of the Rules**.

### 2.2 Submission of Plans and Documents

#### 2.2.1 Plans and Documents for Reference

In addition to the requirements specified in the **1.2(2)**, the following **(1)** to **(3)** are to be submitted:

- (1) data relating to the thermal deformation of the low temperature parts,
- (2) piping and pipe connection procedures, and
- (3) casing insulation procedures.

### 2.3 Materials, Construction and Strength

#### 2.3.1 Materials

1 Materials used for main structural parts are to be suitable for their respective working conditions, such as service temperatures, pressures, etc. In addition, materials to be used for pressure-bearing parts are to be in accordance with relevant requirements in **Part K of the Rules**.

2 Materials used for main structural parts whose design temperatures do not exceed -55°C are to be in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.

3 The non-destructive tests specified in **5.1.10** or **6.1.10, Part K of the Rules** may be requested for main structural parts in cases where deemed necessary by the Society.

4 The main structural parts of gas compressors specified in this chapter, in general, refer to the following **(1)** to **(3)**.

- (1) Centrifugal gas compressors
  - (a) Impellers
  - (b) Inducers,
  - (c) Guide vanes
  - (d) Casings
  - (e) Shafts and couplings
- (2) Displacement gas compressors
  - (a) Cylinder covers and cylinder liners
  - (b) Pistons and piston rods/connecting rods
  - (c) Crankshafts and shaft couplings
  - (d) Beds
  - (e) Screws or gears (rotary type only)

- (f) Casings (rotary type only)
- (3) Others as required by the Society according to structural type

### **2.3.2 Construction and Installation**

- 1** Gas compressors are to be free from gas leakage as far as practicable and to be of a non-sparking construction.
- 2** Low temperature parts of gas compressors are to be of a thermally protected construction so as not to be adversely affected by any temperature differences with connected parts at room temperatures or high temperatures.
- 3** The shaft sealing of gas compressors is to be according to the following **(1)** and **(2)**:
- (1) Sufficient gas sealing ability at service temperature and pressure is to be provided, and construction is to be durable enough to permit continuous operation;
- (2) Construction is to be such that no gas leakage or ingress of atmospheric air occurs when the gas compressor comes to stop.
- 4** Suitable means are to be provided so that no excessive forces are imposed upon gas compressors due to any deformation of the piping connected thereto and ship deflections.
- 5** In cases where gas compressors are driven by steam turbines installed in the same compartment, the temperature of the steam to drive the turbine is to be sufficiently safe by being lower than the spontaneous ignition temperature of boil-off gas.
- 6** Gas compressors, including driving machines and power transmission systems, are to be capable of withstanding the mechanical and thermal loads, and vibrations encountered under normal working conditions. In addition, they are to be capable of continuing undisturbed operation at the angles of inclination specified in the upper column of **Table D1.1, Part D of the Rules**.
- 7** In cases where the generation of harmful surging is likely at low loads depending upon the type of gas compressor, effective preventive means, such as the provision of recirculation lines, are to be taken.
- 8** In cases where excessive temperature rise due to recirculation is anticipated, effective preventive means are to be taken.
- 9** Gas compressors are to be constructed so as to allow gas purging without difficulty at times of overhauling and are to be provided with suitable purge connections.

### **2.3.3 Strength**

- 1** Gas compressors are to be designed with due consideration given to the following **(1)** to **(11)**:
- (1) maximum fuel vapour pressure under service conditions,
- (2) internal casing pressure,
- (3) local loads imposed by connected piping and supports,
- (4) thermal stress,
- (5) impact or vibration loads due to contact or rotation (as necessary),
- (6) load imposed by a static heel angle of 30°,
- (7) own weights of structural parts and attached insulation materials,
- (8) loads imposed by rotation,
- (9) unbalanced weight and equipment vibrations (reciprocating-type gas compressors only),
- (10) axial thrust, and
- (11) other pressures and loads deemed necessary by the Society.
- 2** The thicknesses of casings and cylinders serving as pressure-bearing parts of gas compressors are, in principle, to use the maximum internal pressure obtained from **-1**, and to have values not less than those determined by the requirements in **10.5 to 10.7, Part D of the Rules**. The Society may request the submission of direct calculations sheets in cases where deemed necessary.
- 3** The values required for type *C* independent tanks in **6.4.15-3(3)(a), Part GF of the Rules** are, in principle, to be the allowable stress values used in the calculations in **-2** above.

4 The values for efficiency of welded joints and corrosion allowance used in -2 above are to be those specified respectively in **10.4.2** and **10.4.3, Part D of the Rules**.

5 The strength of main structural parts which undergo rotating or reciprocating motions is to be as deemed appropriate by the Society.

## **2.4 Safety Devices**

### **2.4.1 General**

Gas compressors are to be provided with protective equipment and monitoring systems to sufficiently ensure safe and stable operating performance according to compressor type and service conditions.

### **2.4.2 Monitoring Systems and Safety Devices**

1 Gas compressors are to be as specified in **Part GF of the Rules**. In addition, they are to be provided with suitable monitoring systems, alarm systems and safety devices capable of dealing with the following **(1)** to **(11)**:

- (1) abnormal increases in gas outlet temperatures,
- (2) low lubricating oil pressures,
- (3) low sealing liquid pressures of shaft seal assemblies,
- (4) stopping of cooling water supply and abnormal increases of cooling water outlet temperatures,
- (5) loss of control power,
- (6) surging,
- (7) low sealing liquid pressures of bearings,
- (8) continuous operation of volumetric compressors in barred speed ranges,
- (9) over speed,
- (10) abnormally low temperatures at boil-off gas heater outlets, and
- (11) others deemed necessary by the Society according to operating system.

2 The driving units of gas compressors are, in principle, to be provided with the safety devices specified in **3.3** and **4.3, Part D of the Rules** and **2.3, Part H of the Rules** depending upon the type of unit.

### **2.4.3 Emergency Stopping Systems**

Gas compressors are to be provided with emergency stopping systems which can be operated locally as well as remotely from a control station.

### **2.4.4 Critical Speed**

1 Critical speeds of centrifugal-type gas compressors are not to fall within the following **(1)** and **(2)** ranges:

- (1) Rigid shafts: equal to or less than 120% of the maximum service speed (*rpm*); and
- (2) Flexible shafts: equal to or less than 85% of the minimum service speed (*rpm*) for the primary critical speed and equal to or less than 120% of the maximum service speed for the secondary primary critical speed (*rpm*).

2 Service speeds (*rpm*) of reciprocating type gas compressors are not to be set within  $\pm 10\%$  of the natural frequencies of rotating shafting systems.



## **2.5 Accessory Installations**

### **2.5.1 Lubricating Systems**

**1** Lubricating systems of gas compressors whose bearings are forced lubricated are to be in accordance with the following **(1)** to **(5)**:

- (1) The system is sufficient for providing lubrication at start-up and stopping.
- (2) The lubricating oil strainers are to be capable of being renewed during the operation of gas compressors.
- (3) The system is capable of maintaining lubricating oil temperature at a reasonable level.
- (4) The system is provided with a lubricating oil sump sufficient in capacity to contain the lubricating oil in the amount necessary for ordinary operation, even when the compressor is not in operation.
- (5) The system is of such a construction that no ingress of gas into the lubricating oil is permitted. This requirement, however, may be dispensed with in cases where mixing with gas is presumed to be part of the design for structural reasons.

**2** Lubricating oil systems of the driving units of gas compressors and power transmission systems are to comply with the requirements in **3.3.3**, **4.4.6** or **5.2.5, Part D of the Rules** depending upon the type of system.

## **2.6 Tests and Inspections**

### **2.6.1 Tests and Inspections During Manufacturing**

**1** Pressure-bearing parts of compressors are to be subjected to hydraulic tests or pressure tests. Pressure tests are to use air or another suitable gas.

**2** Compressors are to be subjected to operating tests upon completion of manufacturing, but prior to installation on board ship. The tests are to use a gas deemed appropriate by the Society according to design temperature.

**3** Compressors are to be subjected to the service tests specified in **16.7.3-5, Part GF of the Rules**.

## Chapter 3 FUEL PUMPS

### 3.1 General

#### 3.1.1 Application

1 The requirements in this chapter apply to submerged type, deepwell type and deck-mounted type centrifugal pumps according to the requirements in **1.1.3-1, Part GF of the Rules**.

2 Driving motors of fuel pumps are to comply with the requirements in this chapter and also with relevant requirements in **Part H** and **Part GF of the Rules**.

### 3.2 Submission of Plans and Documents

#### 3.2.1 Plans and Documents for Reference

In addition to the plans and documents specified in **1.2(2)**, the following **(1)** and **(2)** are to be submitted for reference:

- (1) data related to thermal deformation of the low temperature parts; and
- (2) sectional assembly plans for driving motors of submerged type pumps which indicate total rating, principal dimensions, materials (including electrical insulation materials) and weight.

### 3.3 Materials, Construction and Strength

#### 3.3.1 Materials

1 Materials used for main structural parts are to be suitable for their respective working conditions, such as service temperatures, pressures, etc. In addition, pressure-bearing parts are to be in accordance with relevant requirements in **Part K of the Rules**.

2 Materials used for main structural parts whose design temperatures do not exceed -55°C are to be in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4 in Part GF of the Rules**.

3 The non-destructive tests specified in **5.1.10** or **6.1.10, Part K of the Rules** may be requested for structural parts in cases where deemed necessary by the Society.

4 The main structural parts of the pumps specified in this chapter, in general, refer to those in the following **(1)** to **(5)**:

- (1) casings (including fuel discharge outlet in the case of deepwell type),
- (2) impellers,
- (3) inducers
- (4) shafts and shaft couplings, and
- (5) others as required by the Society according to structural type.

#### 3.3.2 Construction and Installation

1 Pumps are to be of a non-sparking construction.

2 Pumps are to be such that sufficient consideration is given to preventing the generation of cavitation.

3 The electrical insulation materials and insulated cables of the driving motors of submerged type pumps are to sufficiently withstand the service environment, and the insulation resistance of the motor is not to be less than the value specified in **2.4.15-5, Part H of the Rules**.

4 Pumps dealing with fuel at low temperatures are to be of a construction which gives sufficient consideration to the effects of thermal contraction.

**5** The shaft sealing assemblies of deepwell type pumps and deck-mounted type pumps are to be of the construction specified in **2.3.2-3**.

**6** Pumps are to be provided with suitable means to prevent them from be subject to undue loads due to deformation of the piping connected thereto as well as fuel tank and ship deflection.

**7** Suitable strainers in accordance with the relevant fuel properties are to be provided at the suction parts of pumps as necessary.

### **3.3.3 Strength**

**1** Pumps are to be designed with due consideration given to the combinations of the pressures and loads specified in the following **(1)** to **(8)**:

- (1) maximum fuel vapour pressure at service condition,
- (2) fuel discharge pressure,
- (3) local loadings imposed by connected piping and supports,
- (4) shaft thrust,
- (5) thermal stress,
- (6) own weight,
- (7) loads due to rotation, and
- (8) other pressures and loads deemed necessary by the Society.

**2** The thicknesses of the pressure-bearing parts of pumps are, in principle, to use the maximum internal pressures obtained from -1 above and are to have values not less than those determined by the requirements in **10.5** to **10.7, Part D of the Rules**. The Society may request the submission of direct calculations sheets in cases where deemed necessary.

**3** The values required for type *C* independent tanks in **6.4.15-3(a), Part GF of the Rules** are, in principle, to be the allowable stress values used in the calculations in -2 above.

**4** The values used for efficiency of welded joints and corrosion allowance used in the calculations in -2 above are to be the values respectively in **10.4.2** and **10.4.3, Part D of the Rules**.

**5** The strength of main structural parts, such as shafts, shaft couplings and impellers (excluding pressure-bearing parts) is to be as deemed appropriate by the Society.

## **3.4 Safety Devices**

### **3.4.1 General**

Pumps are to be provided with safety devices and monitoring systems to sufficiently ensure safe and stable operating performance according to pump type and service conditions.

### **3.4.2 Monitoring Systems and Safety Devices**

Pumps are to be in accordance with provided specified in **Part GF of the Rules**. In addition, and they are to be provided with suitable monitoring systems, alarm systems and safety devices capable of dealing with the following **(1)** to **(3)**:

- (1) low discharge pressures,
- (2) over currents and abnormal drops of current, and
- (3) others deemed necessary by the Society.

## **3.5 Accessory Installations**

### **3.5.1 Lubricating Systems**

**1** Sufficient consideration is to be given to prevent the ingress of foreign matter into pumps whose lubrication is effected by forced circulation, such as by providing filters at the inlets of the

lubricating fuel liquid, etc.

2 Sufficient consideration is to be given to properties closely related to lubrication, such as viscosity and temperature, as well as compatibility with bearing materials for pumps whose lubrication is effected by forced circulation.

### 3.6 Tests and Inspections

#### 3.6.1 Type Tests

1 Each size and type of pump is to be subjected to design assessments and type tests.

2 The type tests specified in -1 above are to be the tests and inspections specified in the following (1) to (5). Such tests and inspections, however, may be substituted for by manufacturer tests and inspections in cases where deemed appropriate by the Society.

(1) Material tests are to be carried out in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.

(2) Hydraulic tests or pressure tests are to be carried out on pressure-bearing parts at test pressures 1.5 times design pressure. Pressure tests are to use air or another suitable gas.

(3) Operating tests are to be carried out on pumps according to design temperature. Capacity tests are to be carried out on submerged electric motor driven pumps, and such tests are to use the fluid the pump is designed to handle or a fluid deemed appropriate by the Society at a test temperature not exceeding the minimum working temperature of the pump. Capacity tests for shaft driven deep well pumps test may be carried out using water, but spin tests at the minimum design temperature are also to be carried out to verify there are no abnormalities present in bearing clearances, wear rings and sealing arrangements. The full length of shafting is not required for spin tests, but the test length must be sufficient to include at least one bearing and sealing arrangements.

(4) Pumps are to be opened up and inspected for abnormalities upon completion of the tests specified in (3) above.

(5) Other tests and inspection deemed necessary by the Society according to pump type.

#### 3.6.2 Product Inspections

1 Pumps are to be subjected to the tests and inspections specified in the following (1) to (3) during manufacturing:

(1) Material tests are to be carried out in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.

(2) Pressure-bearing parts of pumps are to be subjected to hydraulic tests or pressure tests at a test pressure of 1.5 times design pressure. Pressure tests are to use air or another suitable gas.

(3) Pumps are to be subjected to operating tests according to design temperature. Submerged electric motor driven pumps are to be subject to capacity tests. Such tests are to be carried out using the fluid the pump is designed to handle or a fluid deemed appropriate by the Society at a test temperature not exceeding the minimum working temperature of the pump. Capacity tests for shaft driven deep well pumps may be carried out using water.

2 Pumps are to be subjected to the service tests specified in **16.7.3-5, Part GF of the Rules** after installation on board ship.

## Chapter 4      HEAT EXCHANGERS

### 4.1      General

#### 4.1.1      Application

The requirements in this chapter apply to heat exchangers in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### 4.2      Materials, Construction and Strength

#### 4.2.1      Materials

1    Materials used for structural parts which come in contact with fuel liquids or vapours are to be in accordance with relevant requirements in **Part K of the Rules** and in **7.4, Part GF of the Rules**.

2    Materials used for structural parts which do not come in contact with fuel liquids or vapours are to be as deemed appropriate by the Society depending upon the type of refrigerant or heating media used as well as design temperature and design pressure.

#### 4.2.2      Construction and Strength

1    Structural parts which come in contact with fuel liquids or vapours are to be designed in accordance with requirements relative to Group 1 pressure vessels and heat exchangers specified in **Chapter 10, Part D of the Rules** regardless of design temperature and design pressure.

2    Structural parts which do not come in contact with fuel liquids or vapours are to be as deemed appropriate by the Society depending upon the type of refrigerant or heating medium used as well as design temperature and design pressure.

3    Heat exchangers whose design temperatures are below  $-55^{\circ}\text{C}$  are to be subjected to strength analysis for thermal stress.

### 4.3      Tests and Inspections

#### 4.3.1      Prototype Tests

Prototypes of heat exchangers for fuel liquids, vapours or refrigerants used at temperatures below  $-55^{\circ}\text{C}$  are to be subjected to tests deemed appropriate by the Society depending upon the type of heat exchanger. The tests are to verify that heat exchanger performance is satisfactory.

#### 4.3.2      Product Inspections

1    All heat exchangers are to be tested in accordance with the requirements in **10.9, Part D of the Rules**.

2    Airtightness tests at design pressures at temperatures below design temperatures may be required in cases where deemed necessary by the Society.

3    Heat exchangers are to be subjected to service tests in accordance with the requirements in **16.7.3-5, Part GF of the Rules** after installation on board ship.

## Chapter 5 VALVES

### 5.1 General

#### 5.1.1 Application

The requirements in this chapter apply to valves directly fitted onto fuel tanks, interbarrier spaces or process pressure vessels and valves for fuel and process piping in accordance with the requirements in **1.1.3-1, Part GF of the Rules**. Relief valves subject to the requirements in **Chapter 6**, however, are exempt from these requirements.

### 5.2 Materials, Construction and Strength

**1** Materials used for the main pressure-bearing parts of valves are to be in accordance with the following **(1)** and **(2)**:

- (1)** Be ones in accordance with relevant requirements in **7.4, Part GF of the Rules** and **Part K of the Rules**; however, materials for the valves of the piping specified in the following **(a)** to **(c)** may be those which meet the *JIS* or other standards deemed appropriate by the Society, but only on the condition they satisfy the requirements in **7.4, Part GF of the Rules**.
  - (a)** Valves used for fuel piping and process piping whose design pressures do not exceed 1 MPa and whose design temperatures are 0°C or higher.
  - (b)** Valves used for fuel piping and process piping whose design pressures do not exceed 3 MPa, whose design temperatures are 0°C or higher and whose nominal diameters are less than 100 A.
  - (c)** Valves used for accessory piping or instrumentation piping whose diameters do not exceed 25 mm regardless of design pressure and design temperature.
- (2)** Notwithstanding the requirements in **(1)** above, valves of piping having open ends which do not come in contact with the fuel liquids led from the pressure-relieving valves of fuel tanks and fuel piping or process piping whose design temperatures are -55°C or higher.

**2** Valves whose design temperatures are below -55°C are to be subject to the type tests specified in **16.7.1, Part GF of the Rules** and approved for use as specified in the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

**3** The construction and strength of valves are to be in accordance with the *JIS* or other standards deemed appropriate by the Society.

**4** For valves not conforming to the requirements in **-3** above, detailed data on construction and strength are to be submitted to the Society and the valves are subject to the type approval specified in the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

### 5.3 Tests and Inspections

#### 5.3.1 Type Tests

The tests specified in **5.2-2** above are to be the tests and inspections specified in the following **(1)** to **(9)**:

- (1)** Material tests are to be carried out in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.
- (2)** Pressure tests are to be conducted at pressures 1.5 times design pressure at room temperatures.
- (3)** Airtightness tests are to be conducted after assembly at 1.1 times design pressure at room

temperature.

- (4) Leakage verification tests are to be carried out over the entire range of working temperatures and working pressures up to 1.1 times design pressure for the increments given in **Table 5.1**. For valves which are capable of sealing in both directions, tests are to be conducted for each direction. For valves having a tendency of greater leakage at low pressures, additional leakage tests are to be conducted at temperatures not exceeding the design pressures designated by the Society. There is, in principle, to be no leakage at all in tests at room temperature. In tests at low temperatures, however, there is to be no leakage exceeding the rate of leakage deemed appropriate by the Society.
- (5) Operating tests at low temperatures are to be carried out at least 20 times at temperatures not exceeding minimum design temperature. Upon completion of these tests, leakage tests are to be conducted to verify that there is no significant difference between the results of these tests and the ones carried out in (4) above. Upon completion of the second series of leakage tests, the leakage tests specified in (4) above are to be carried out once again at room temperature to verify that there is no leakage.
- (6) Valves are to be opened up and inspected for abnormalities upon completion of the tests specified in (5) above.
- (7) Flow or capacity tests carried out in accordance with standards deemed appropriate by the Society to verify the amount of flow or capacity.
- (8) Fire tests which are in accordance with *ISO 19921:2005* and *ISO 19922:2005* are to be carried out on emergency shutdown valves whose materials have melting temperatures lower than 925°C.
- (9) Other tests and inspection as deemed necessary by the Society depending upon the type of valve.

Table 5.1 Increments in Leakage Verification Tests

Design pressure (MPa)	Increment <sup>(1)</sup> (MPa)
2.0 and below	0.35
5.0 and below	0.75
6.4 and below	1.0
10.0 and below	2.0

Note:

(1) For valves whose design pressures exceed 10.0 MPa, the increments are to be as deemed appropriate by the Society

### 5.3.2 Product Inspections

1 Valves are to be subjected to the test and inspection items specified in the following (1) to (4) during manufacturing:

- (1) Material tests are to be carried out in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.
- (2) Hydraulic tests are to be carried out at room temperature at test pressures 1.5 times design pressure. For valves intended to be fitted directly onto type C independent tanks, tests are to be conducted at pressures twice design pressure. Tests are to be in accordance with the requirements in **16.7.3-2, Part GF of the Rules** in cases where a medium other than water is used.
- (3) Airtightness tests are to be carried out at room temperature at 1.1 times design pressure.
- (4) Leakage verification tests are to be carried out for the valve seats of all valves at room temperature at 1.1 times design pressure. For valves whose design temperatures are below -55°C, at least 10% of the total number of valves is to be tested at temperatures not exceeding

minimum design temperature and pressures not less than 1.1 times design pressure for each size and type of valve. In cases where any of the above-mentioned samples tested fail, all or some of the remaining valves, the exact amount to be determined by the Society, not subjected to the tests are required to be tested at temperatures not exceeding minimum design temperature.

**2** Valves are to be subjected to the service tests specified in **16.7.3-3** and **16.7.3-5, Part GF of the Rules** after installation on board ship.

**3** The presence of a Society surveyor for test and inspection items specified in **-1** above, excluding the leakage verification tests for valve seats to be conducted at temperatures not exceeding the minimum design temperatures specified in **-1(4)**, may be reduced in cases where the valve manufacturer has been separately assessed and approved in accordance with the “**Rules for Approval of Manufacturers and Service Suppliers**” and reports of the test and inspection items concerned carried out by the manufacturer are submitted.



## Chapter 6 RELIEF VALVES

### 6.1 General

#### 6.1.1 Application

**1** The requirements in this chapter apply to the relief valves (including vacuum relief valves) used for fuel containment systems, process pressure vessels, fuel piping and process piping in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

**2** Unless otherwise specified, the application of some of the requirements in this chapter to relief valves fitted to process pressure vessels, fuel piping and process piping may be dispensed with when deemed appropriate by the Society.

### 6.2 Materials, Construction and Strength

#### 6.2.1 Materials

**1** Materials used for the main structural parts of relief valves whose design temperatures are not below 0°C are to be in accordance with relevant requirements in **Part K of the Rules**. For the main structural parts of relief valves whose design pressures are less than 3 MPa and whose nominal diameters are less than 100 A, however, materials which satisfy the JIS or other standards deemed appropriate by the Society may be used.

**2** Materials of the main structural parts of relief valves whose design temperatures do not exceed 0°C are to be in accordance with relevant requirements of **Part K of the Rules** and **Table GF7.4, Part GF of the Rules**.

**3** The term “main structural parts” as used in **-1** and **-2** above refers to pressure-bearing parts and other parts designated by the Society depending upon the type of relief valve.

#### 6.2.2 Construction, etc.

**1** Relief valves fitted for use on type C independent tanks and process pressure vessels are to be of the following **(1)** or **(2)** types. In cases where valves of other types are used, approval is required to be obtained from the Society on a case-by-case basis.

**(1)** For relief valves of a high lift type (i.e., valve lift is not less than 1/15, but not more than 1/7 of the diameter of valve seat), the minimum areas of passage at the chest inlet and outlet are not to be respectively less than the required valve seat area or 2 times the required valve seat area.

**(2)** For full bore valves (i.e., valve seat diameter is not less than 1.15 times throat diameter), the passage area of the valve seat when the valve is open is not to be less than 1.05 times throat area, and the minimum passage area of the discharge outlet is not to be less than 2 times the passage of the valve seat.

**2** The construction of spring-loaded relief valves and the respective discharge pipes are to be in accordance with **-12** and **-13** of **9.9.3, Part D of the Rules**. In addition, JIS B 8210 or another standard deemed appropriate by the Society is to be satisfied.

**3** The construction of the pilot type relief valves is to be as deemed appropriate by the Society. In such cases, those with non-metal diaphragms or membranes are to be in accordance with the following **(1)** to **(3)** requirements:

**(1)** Be capable of safely discharging vapour even when exposed to fire. Operating verification tests under fire conditions may be requested in cases where deemed appropriate by the Society.

**(2)** Valve lifting gear deemed appropriate by the Society is to be provided in cases where deemed necessary.

(3) Non-metallic membranes are to be durable for a period not less than 3 years.

4 Relief valves are to be provided with sealing means deemed appropriate by the Society and popping pressures are to be set in the presence of a Society surveyor, and, at the same time, means are to be provided to allow easy verification that no adjustments are made afterwards.

### 6.2.3 Strength

Relief valves are to be designed with due consideration given to proper combinations of the pressures and loads as listed in the following (1) to (7):

- (1) design pressures of the fuel tanks, interbarrier spaces, hold spaces, process pressure vessels and fuel piping or process piping to which the relief valves are fitted;
- (2) relief valve set pressure;
- (3) additional loads imposed by connected piping;
- (4) loads applied by springs, diaphragms or membranes;
- (5) impact loads which may be generated when the relief valve is in use;
- (6) thermal stress; and
- (7) other pressures and loads deemed necessary by the Society.

## 6.3 Relieving Capacity

### 6.3.1 Relieving Capacities of Relief Valves

The relieving capacities of relief valves may be evaluated by the following equation. In cases where different type fuels or fuels with different mixing ratios are being carried, relieving capacity is to be sufficient for either of the fuels.

$$W = KCAP \sqrt{\frac{M}{ZT}}$$

where

$W$ : relieving capacity of relief valve ( $kg/h$ )

$A = \pi DL$  ( $cm^2$ , in the case of high lift type valves)

$A = \frac{\pi}{4} D_t^2$  ( $cm^2$ , in the case of full bore type valves)

$D$ : diameter of valve seat ( $cm$ )

$L$ : valve lift ( $cm$ )

$D_t$ : throat diameter ( $cm$ )

$P$ : absolute pressure of 1.2 times *MARVS* of the tank ( $MPa$ , ata)

$P'$ : absolute pressure at valve exit ( $MPa$ , ata)

$M$ : molecular weight of fluid

$T$ : absolute temperature of fluid at pressure  $P$  ( $K$ )

$Z$ : compression coefficient of fluid gas at pressure  $P$  and temperature  $T$  (1 is to be used where  $T$  is unknown)

$K$ : the value determined by the prototype test specified in the following 6.4.1.

$C$ : value determined by the following formula

$$(1) \text{ In cases where } \frac{P'}{P} \leq \left( \frac{2}{k+1} \right)^{\frac{k}{k-1}}$$

$$C = 3943 \cdot \sqrt{k \left( \frac{2}{k+1} \right)^{\frac{k+1}{k-1}}}$$

(2) In cases where  $\frac{P'}{P} > \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$

$$C = 5584 \cdot \sqrt{\frac{k}{k-1} \left[ \left(\frac{P'}{P}\right)^{\frac{2}{k}} - \left(\frac{P'}{P}\right)^{\frac{k+1}{k}} \right]}$$

$k$  = specific heat of fluid at pressure  $P$  and temperature  $T$  (values in standard condition may be used)

## 6.4 Tests and Inspections

### 6.4.1 Prototype Tests

**1** Relief valves, not including those whose design temperatures are -55°C or higher, fitted to fuel piping and process piping, are to be subjected to prototype tests. The tests are to verify that the relief valves possess necessary performance.

**2** Prototype tests are to be conducted in accordance with test plans approved by the Society. Test plans are to include details of procedures for verifying the following (1) to (9) items depending upon the type of relief valve. Parts of such tests (not including (1), (3), (4) and (5)) may be dispensed with for valves having sufficient service records and deemed appropriate by the Society.

- (1) Strength of relief valve casings, including verifying strength at design temperature and a hydraulic test carried out at a test pressure 2 times design pressure. Relief valves other than those fitted directly on type C independent tanks and process pressure vessels, however, may be tested at a test pressure 1.5 times design pressure.
- (2) Strength of valve discs and valve seats, including verifying strength at design temperature.
- (3) Rate of vapour leakage through the valve seat, including verifying at design temperature.
- (4) Relieving capacity and coefficient of discharge (value of K) (in accordance with the requirements in 6.4.2).
- (5) Operation at design temperature and at set pressure. The valve is to be operated at least 20 times if design temperature is below -55°C.
- (6) Static strength and fatigue strength of membranes and bellows, including verifying strength at design temperature.
- (7) Compatibility of structural materials with the fuel vapour and characteristics of aging deterioration under the intended atmosphere, particularly for non-metallic materials exposed to fuel vapours.
- (8) Operating test under fire conditions. This, however, is only applicable in cases where non-metal bellows or membranes are used.
- (9) Others as deemed necessary by the Society depending upon the type of relief valves.

**3** For the relief valves with non-metallic membranes, the renewal intervals of non-metallic membranes may be extended to more than 3 years to a length of time approved by the Society in consideration of the results of the tests specified in (6), (7) and (9) of -2 above.

### 6.4.2 Capacity Tests

**1** Tests to measure relieving capacities and coefficients of discharge (hereinafter referred to as "capacity tests") are to be carried out when the coefficient K is intended to be increased from the value approved during prototype tests or to another previously approved value.

**2** Capacity test procedures are to be in accordance with the following or other methods deemed appropriate by the Society.

- (1) In cases where  $\frac{P_2}{P_1} \leq \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$

To be accordance with *JIS B 8225* “Measuring Method of Blow-off Coefficient of Relief Valves”.

- (2) In cases where  $\frac{P_2}{P_1} > \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$

Capacity tests are to be carried out for each size of valves to be used and the coefficient of discharge for each size valve is to be determined from the results of the capacity test.

$P_1$ : absolute pressure at valve inlet

$P_2$ : absolute pressure at valve exit

$k$ : specific heat of fluid

**3** Measurements in capacity tests are, in principle, to be taken using orifices placed in the upstreams of test relief valves.

**4** Test gas, unless otherwise specified, is to be air which may be dealt with as a gas that changes its state according to the following equation:

$$\gamma = \frac{P}{RT}$$

where

$\gamma$ : weight of unit volume ( $kg/m^3$ )

$T$ : absolute temperature (K)

$P$ : absolute pressure (MPa)

$R$ : gas constant of air (=2.89)

**5** Coefficients of discharge measured by capacity tests may be used as the value  $K$  specified in **6.3** for designs by multiplying the value by a constant specified by the Society (normally, 0.9) depending upon the test method.

### 6.4.3 Manufacturing Plant Tests

**1** Individual relief valves are to be subjected to the following tests **(1)** to **(3)** after manufacturing:

- (1) Hydraulic tests are to be carried out on pressure-bearing parts at test pressures 2 or more times design pressure. Relief valves other than those fitted directly onto type *C* independent tanks and process pressure vessels, however, may be tested at 1.5 times design pressure.
- (2) Airtightness tests of valve seats are to be conducted at pressures in the proximity of the set pressure of the relief valve (at least 90% of the set pressure).
- (3) Performance tests are to be carried out to verify relieving pressures, blowdown pressures, valve lift and other operating conditions.

**2** Relieving pressures in performance tests are to be checked to verify whether they are within the allowable ranges specified in the following **(1)** to **(3)**. In addition, relief valves are to be sealed in the presence of the Society surveyor after such tests.

- (1) Relieving pressure is 0 MPa or more, but less than 0.15 MPa:  $\pm 10\%$
- (2) Relieving pressure is 0.15 MPa or more, but less than 0.3 MPa:  $\pm 6\%$
- (3) The relieving pressure is 0.3 MPa or more:  $\pm 3\%$

## Chapter 7      BELLOWS AND EXPANSION JOINTS (For Fuel Piping and Process Piping Systems)

### 7.1      General

#### 7.1.1      Application

1    The requirements in this chapter apply to bellows and expansion joints used for fuel piping and process piping systems in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### 7.2      Materials, Construction and Strength

#### 7.2.1      Materials

1    Materials used for the main structural parts of bellows and expansion joints whose design temperatures are below 0°C are to be in accordance with relevant requirements in **Part K of the Rules** and **Table GF7.4, Part GF of the Rules** regardless of design pressure and nominal diameter.

2    Materials for the main structural parts of bellows and expansion joints whose design temperatures are not less than 0°C and which are specified in the following (1) or (2) may be those which meet the *JIS* or other standards deemed appropriate by the Society, but only on the condition that they satisfy the requirements in **Table GF7.4, Part GF of the Rules**.

(1) Those used for fuel piping and process piping whose design pressures do not exceed 3 MPa, whose design temperatures are 0°C or higher and whose nominal diameters are less than 100 A.

(2) Those used for accessory piping or instrumentation piping whose diameters do not exceed 25 mm regardless of design pressure and design temperature.

3    The term “main structural parts” as used in -1 and -2 above refers to flanges and bellows, but does not include control rings and guide bars.

4    The use of low carbon steel is recommended for bellows of austenitic stainless steel. In addition, when austenitic stainless steel is used, solid solution heat treatments and passivation treatments are, in principle, to be carried out after the completion of welding and plastic processing.

#### 7.2.2      Construction and Strength

1    Design pressures of bellows and expansion joints used for fuel liquid piping systems are not to be less than 1.0 MPa. This requirement, however, may be dispensed with for bellows or expansion joints used for fuel liquid piping systems with open pipe ends within fuel tanks. In such cases, design pressures are not to be less than 0.5 MPa.

2    Design pressures of bellows and expansion joints used for fuel vapour piping systems with open pipe ends are not to be less than 0.5 MPa.

3    Construction of flanged parts of bellows and expansion joints is to be in accordance with the *JIS* or other standards deemed appropriate by the Society.

4    For bellows and expansion joints used for fuel liquid piping systems, it is recommended that inner sleeves be provided when vibrations caused by flow disturbances within the bellows are likely to occur.

5    In cases where protective covers, such as outer sleeves, are not provided to prevent the external freezing of bellows and expansion joints used in exposed spaces, the bellows and expansion joints are to have geometric configuration precluding any accumulation of water on the outer surfaces.

6    The free lengths of bellows and expansion joints are to have a fabrication accuracy of  $\pm 1\%$  or less upon completion of all fabrication work.

7    The items specified in the following (1) to (4) are to be examined to verify that bellows possess

sufficient strength:

- (1) Static strength of bellows against internal pressure.
- (2) The fatigue life and susceptibility to damage due to cumulative loads of bellows against internal pressure and movement. In such cases, the susceptibility to damage due to fatigue loads is to satisfy the following equation:

$$\sum \frac{n_i}{N_i} + \frac{10^3}{N_j} \leq C_w$$

where

$n_i$ : number of repetitions at each strain level during the service life of the ship (the frequency of encounter with waves is typically assumed to be  $10^8$  times)

$N_i$ : number of repetitions up to failure at each strain level by a calculation equation deemed appropriate by the Society (e.g., as given in **-8(2)**) or by  $\varepsilon$ - $N$  curves

$N_j$ : number of repetitions up to failure due to strain of loading/unloading fuels

$C_w$ : value to be 0.5 or less; however, the Society may accept a value higher than 0.5 depending upon the test method and data used for plotting  $\varepsilon$ - $N$  curves. In such cases,  $C_w$  is not to exceed 1.0.

- (3) Vibration-resisting strength when exposed to vibration
- (4) Bellow stability when subjected to internal pressure and deformation

**8** The fatigue strength of bellows acted upon by internal pressure and axial movement may be evaluated by the requirements specified in the following **(1)** to **(3)**:

- (1) The axial surface strain of bellows due to internal pressure and axial movement is to be determined by either the following equation or actual measurements.

- i) Single-layer bellows and multiple-layer bellows

$$\varepsilon = \frac{1.5t\delta}{W^{0.5} \cdot H^{1.5} \cdot 2n}$$

(strain due to axial movement)

Strain due to internal pressure is to be obtained by calculations deemed appropriate by the Society.

- ii) Bellows with control rings

$$\varepsilon = 0.55 \cdot \frac{1.5t\delta}{W^{0.5} \cdot H^{1.5} \cdot 2n}$$

(strain due to axial movement in cases where bellows do not come in close contact with the ring)

$$\varepsilon = 0.55 \cdot \frac{1.5t\delta}{(W - \gamma_0)^{0.5} \cdot (H - \gamma_0)^{0.5} \cdot 2n}$$

(strain due to axial movement in cases where bellows come in close contact with the ring)

$$\varepsilon = \frac{P(H - \gamma_0)^2}{200 \cdot t^2 E}$$

(strain due to internal pressure)

where

$H$ : height of crown of bellows ( $mm$ )

$t$ : thickness of one sheet of bellows ( $mm$ )

$P$ : internal pressure ( $N/mm^2$ )

$W$ : 1/2 of corrugation pitch of bellows ( $mm$ )

$\gamma_0$ : radius of crown of bellows ( $mm$ , dimension to half the plate thickness)

$n$ : number of crowns of bellows

$\delta$ : equivalent total axial movement ( $mm$ )

$E$ : Young's modulus ( $N/mm^2$ )

- (2) On the basis of the strains obtained from (1) above, the fatigue life at each level of strain is to be determined using the following equation or  $\varepsilon$ - $N$  curves deemed appropriate by the Society:

$$N = \frac{\left(\frac{C}{2}\right)^2}{(\varepsilon_t - 0.65\varepsilon_y)^2} \quad \text{at room temperature}$$

$$N = \frac{2.2\left(\frac{C}{2}\right)^2}{(\varepsilon_t - 0.65\varepsilon'_y)^2} \quad \text{at low temperature } (-162^\circ\text{C})$$

where

$N$ : service life (number of loadings)

$$C = -\frac{1}{2} \log\left(\frac{100 - \phi}{100}\right)$$

where

$\phi$ : contraction percentage

$\varepsilon_t$ : half the amplitude of total strain

$\varepsilon_y$ : strain at 0.2% proof strength at room temperature

$\varepsilon'_y$ : strain at 0.2% proof strength at low temperature ( $-162^\circ\text{C}$ )

- (3) According to 7(2) above, evaluations are to be made on the susceptibility to damage due to cumulative loadings.

9 When subjected to vibratory loads, the resultant stress levels are to be less than the fatigue limit.

10 Where austenitic stainless steel is used for bellows, designs may be developed upon the basis of fatigue strength at room temperature.

## 7.3 Tests and Inspections

### 7.3.1 Type Tests

Bellows and expansion joints, not including those used for piping with open pipe ends and installed in fuel tanks, are to be subjected to the type tests specified in 16.7.2, Part GF of the Rules for each type.

### 7.3.2 Product Inspections

1 All bellows and expansion joints are to be subjected to the following tests and inspections during manufacturing:

- (1) Material tests are to be carried out in accordance with relevant requirements in Table GF7.4, Part GF of the Rules and Part K of the Rules. In cases where the provisions in 7.2.1-1 are applicable, however, submission of mill sheets may only be required.
- (2) Non-destructive tests are to be carried out for butt welded joints of bellows. 100 % of welded joints of the bellows whose design temperatures do not exceed  $-10^\circ\text{C}$ , or whose inside diameters exceed 75 mm are to be subjected to non-destructive tests. Test for other cases are to be as deemed appropriate by the Society, but sampling tests are to be conducted for at least 10% of the bellows.
- (3) Hydraulic tests are to be carried out at room temperature at test pressures 1.5 times design pressure.

- (4) Airtightness tests are to be carried out after completion of the tests specified in (2) above at design pressure.
- 2** All bellows and expansion joints are to be subjected to the tests specified in **16.7.3-3** and **-5**, **Part GF of the Rules** after installation on board ship.



## **Chapter 8      INERT GAS GENERATOR/STORAGE SYSTEM AND LIQUID NITROGEN TANK**

### **8.1      General**

#### **8.1.1      Application**

**1** The requirements in this Chapter apply to inert gas generator/storage system and liquid nitrogen tanks in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

**2** The requirements in this Chapter do not apply to the inert gas generating system utilizing the exhaust gas from boilers and the system of generating nitrogen gas by separating from the atmospheric air. These systems are to be deemed appropriate by the Society.

**3** The air blowers, fuel oil pumps, heat exchangers, automatic combustion control systems and monitoring systems forming an inert gas generator and storage system are to conform to the requirements in this Chapter, and in addition, to the requirements in the relevant Chapters of **Part D** and **Part R of the Rules**.

#### **8.1.2      Definitions**

**1** “Inert gas generator” means a mechanical plant exclusively used for the generation and supply of inert gas utilizing flue gas and includes air blower, combustion chamber, fuel oil pump and burner, gas cooler/scrubber, and automatic combustion control and monitoring equipment.

**2** “Inert gas storage system” means a set of tank or bottles to store nitrogen gas or other inert gases at room temperature, including piping and automatic control valves necessary for discharging inert gas.

**3** “Liquid nitrogen tank” means a set of tank to store nitrogen gas in the form of liquid nitrogen used for fire extinguishing or inerting, associated refrigerating equipment and cold preservation equipment, vapourizer and automatic control valves necessary for gas discharging.

### **8.2      Inert Gas Generators (*IGG*)**

#### **8.2.1      General**

**1** The inert gas generator (hereinafter as *IGG*) is to conform to the requirements in **6.14, Part GF of the Rules**, and in addition, to the requirements in **8.2** of this Chapter.

**2** The *IGG* and inert gas supply piping are to be so designed and arranged as not to allow inert gas to enter enclosed spaces or leaking thereto.

#### **8.2.2      Construction and Installation**

**1** The combustion chamber of the *IGG* is to have such a construction capable of withstanding the contact with flames and ensuring complete burning in a stable manner.

**2** The combustion chamber of *IGG* and associated equipment are to have such a construction as to withstand the discharge pressure of the combustion air supply blower or fan.

**3** The materials of *IGG* and associated piping systems coming to contact with inert gas or its drains are to have sufficient corrosion-resistance by taking into account the type of fuel and the chemical composition of the flue gas.

**4** Each *IGG* is to be provided with two or more fuel oil pumps. However, when ample spare parts sufficient to recondition the service pump and its driving equipment in case of failure are provided, provision of only one unit of fuel oil pump may be accepted.

**5** For the possible event of non-compliance of the generated inert gas with the required

composition of inert gas (e.g. at time of start-up) or for system failure, means are to be provided to discharge inert gas into the atmosphere.

**6** *IGG* is to be so arranged that the pressure of inert gas will not exceed the set pressure of the pressure relief valve provided in the fuel containment system to which inert gas is supplied.

**7** *IGG* is to be provided with equipment capable of effectively cooling the combustion chamber and exhaust gas and sufficiently discharging impurities in the exhaust gas.

**8** The cooling water supply pump for the combustion chamber and exhaust gas is to be independent from other uses, and a standby unit of the pump is to be provided. The standby unit may be used another purpose.

**9** *IGG* is to be provided with two or more combustion air supply systems. However, if ample spare parts sufficient to allow easy reconditioning of the equipment in case of failure are provided, only one air supply system may be accepted.

**10** When a separate inert gas blower fan is provided in addition to the combustion air supply system, the fan is to conform to the requirements in the preceding -**9** correspondingly.

**11** At the non-hazardous area where the inert gas supply main penetrates through the foremost bulkhead, a control valve functioning according to the requirements in **8.2.4-3** is to be provided.

**12** In case where only one burner is provided, one complete set of nozzles is to be placed on board the ship.

**13** In case where two or more *IGGs* are provided, a stop valve is to be fitted to supply outlet of each system.

**14** When displacement type blower fan is provided in the inert gas generator, a pressure relief valve is to be fitted to prevent excess pressure on the discharge side of the fan.

### **8.2.3 Drying System**

**1** The refrigerating equipment provided to remove moisture contents from the inert gas is to conform to the requirements in **Chapter 17, Part D of the Rules**.

**2** The drying system of chemical reaction type provided to remove moisture contents from the inert gas is to be at least two units of which one is to be used for ordinary service and the other one is to be for regeneration, and means are to be provided so that they can be transferred automatically at time intervals as deemed appropriate by the Society.

### **8.2.4 Control, Alarm and Safety System**

**1** *IGG* is to be provided with safety system capable of stopping the supply of the fuel to burner in the following cases **(1)** through **(5)**:

- (1) Loss of fire
- (2) Ignition failure
- (3) Interruption of combustion air supply
- (4) High inert gas temperature
- (5) Low water level in the cooling system specified in the preceding **8.2.2-7** or excessively low cooling water supply pressure or flow rate.

**2** In addition to those provided in accordance with the preceding -**1**, *IGG* is to be provided with the safety systems as given in the following **(1)** to **(3)**:

- (1) Prepurging system to prevent explosion in the combustion chamber
- (2) In the case of direct ignition system, a device to prevent the fuel oil valve from assuming the open position before ignition spark is to be provided.
- (3) In the case of automatic ignition system, a device ensuring that the ignition period (the period from opening of the fuel oil valve to the closure of the valve due to ignition failure) is not to exceed 10 sec.

**3** The control valve specified in the preceding **8.2.2-11** is to be so arranged that it automatically closes in the following cases **(1)** through **(10)**:

- (1) Abnormal fall of supply pressure or flow rate of cooling water to the refrigerating equipment specified in the preceding **8.2.2-7**
- (2) Abnormal rise of water level in the cooling system specified in the preceding **8.2.2-7**
- (3) High inert gas temperature
- (4) Interruption of combustion air supply
- (5) Fall of the pressure in the inert gas supply main below 100 *mmAq*
- (6) High inert gas supply main pressure
- (7) High inert gas oxygen concentration exceeding 5 % in volume
- (8) When dew point of the inert gas exceeds the preset value
- (9) Power failure of the valve driving mechanism
- (10) Others as deemed necessary by the Society

**4** The cooling pump specified in the preceding **8.2.2-7** is to be such that it automatically comes to stop in the case specified in the preceding **-3(2)**.

**5** *IGG* is to be provided with visible and audible alarm systems that issue alarms in the following cases **(1)** through **(4)**:

- (1) In cases specified in the preceding **-1** and **-3**
- (2) Low fuel oil supply pressure to the burner
- (3) Loss of power supply to *IGG*
- (4) Loss of control power to *IGG*

**6** An automatic control capable of producing suitable inert gas under all service conditions is to be fitted to *IGG*.

**7** Automatic shutdown of the inert gas system and its components parts are to be arranged on predetermined limits being reached, taking into account the provisions of paragraphs **35.2.2-4** and **35.2.3(2)**, **Part R of the Rules**.

**8** The system is to be designed to ensure that if the oxygen content exceeds 5 % by volume, the inert gas is to be automatically vented to atmosphere.

**9** Instrumentation is to be fitted for continuously indicating and permanently recording the followings, when inert gas is being supplied.

- (1) Pressure of the inert gas mains forward of the non-return devices
- (2) Oxygen content of the inert gas

**10** The indicating and recording devices are to be placed in the cargo control room or engine control room where provided. But where no control rooms is provided, they are to be placed in the continuously manned central control station.

**11** Audible and visual alarms are to be provided, based on the system designed, to indicate failure of the power supply to the indicating devices as referred to in **-9** above.

**12** Two oxygen sensors are to be positioned at appropriate locations in the space or spaces containing the inert gas system. If the oxygen level falls below 19 %, these sensors are to be trigger alarms, which are to be both visible and audible inside and outside the space or spaces and are to be placed in such a position that they are immediately received by responsible members of the crew.

### **8.2.5 Tests and Inspection**

**1** In general, inert gas generating system, before being installed on board the ship, is to be made to a test run at the manufacturing plant.

**2** Inert gas generating system, after being installed in the ship, is to be subjected to the following tests **(1)** through **(4)**:

- (1) Airtightness test
- (2) Performance test of the control system, safety system and alarm system
- (3) Verification test of the rate of inert gas generation
- (4) Combustion operation test

## 8.3 Inert Gas Storage System

### 8.3.1 Construction and Piping

- 1 Bottles with an internal volume of not more than 500 l used for the storage of nitrogen gas or other inert gases at room temperature and high pressure may be to the requirements of the national standards.
- 2 Bottles with an internal volume of more than 500 l used for the storage of nitrogen gas or other inert gases at room temperature and high pressure are to conform to the requirements in **Chapter 10, Part D of the Rules**.
- 3 Those gas piping systems for the bottles to store nitrogen gas or other inert gases are to be correspondingly in accordance with the requirements specified in **Chapter 12, Part D of the Rules** relating to carbon dioxide gas depending on the design pressure.
- 4 The equipment for controlling the inert gas from the inert gas storage system is to be to the satisfaction of the Society depending on the inert gas storage system and the construction of the tanks or compartments to be inerted.

## 8.4 Liquid Nitrogen Tanks

### 8.4.1 Construction and Materials

The construction and materials of the tanks for the storage of liquid nitrogen are to conform to the following requirements (1) to (3):

- (1) The construction, strength, tests and inspection of the inner shell of the liquid nitrogen tank are to conform to the requirements for type C independent tank in **Chapter 6** and **Chapter 16, Part GF of the Rules** correspondingly.
- (2) The construction, strength, tests and inspection of the outer shell of the liquid nitrogen tank are to be to the satisfaction of the Society depending on the degree of vacuum in the space between the inner and outer shells and inner tank supporting systems.
- (3) The materials used for the liquid nitrogen tank are to conform to the requirements given in **Table GF7.1 to Table GF7.5, in Part GF of the Rules** depending on the design temperature.

### 8.4.2 Pressure Relief Valves

- 1 Liquid nitrogen tanks are to be provided with two or more pressure relief valves of nearly the same capacity. However, for tanks with a capacity not more than 20 m<sup>3</sup>, only one pressure relief valve may be provided.
- 2 The set pressure and capacity of the pressure relief valves specified in the preceding -1 are to conform to the requirements in **6.7.2** and **6.7.3, Part GF of the Rules** correspondingly.

### 8.4.3 Insulation

- 1 The insulation materials are to conform to the requirements in **6.4.13, Part GF of the Rules**.
- 2 The construction and arrangement of vacuum pump and other items of equipment necessary for the maintenance of vacuum in the space between the inner and outer shells are to be to the satisfaction of the Society.
- 3 When part or whole of the insulation materials are of the inner shell supporting construction of tanks, the Society may require tests in addition to those specified in the requirements in the preceding -1.

### 8.4.4 Filling Limits for Liquid Nitrogen

The filling volume of tank for liquid nitrogen is not to exceed the filling limits determined

according to the requirements in **6.8, Part GF of the Rules**, correspondingly.

#### **8.4.5 Vapourizers**

- 1** The construction and arrangement of vapourizers are to be to the satisfaction of the Society.
- 2** For vapourizers, control systems for supply nitrogen temperature, pressure and flow rate as deemed appropriate by the Society depending on the type and construction system of the compartment or space to which the vapourized nitrogen is supplied are to be provided.

#### **8.4.6 Protections of Hull**

Suitable protective means are to be provided to prevent the hull structures in the vicinity of the tank from being exposed to the liquid nitrogen in the possible event of its leakage.

#### **8.4.7 Instrumentation**

- 1** One or more level gauging devices complying with the requirements in **Chapter 9** are to be provided in tanks.
- 2** Pressure gauges are to be provided in the gaseous phase of the tank. The pressure is, as a rule, to be displayed in the continuously manned control station, and high pressure alarm is to be made available.
- 3** Means are to be provided to take measurements on the liquid temperatures at spaces near the top and bottom of the tank.

#### **8.4.8 Low Temperature Tests, etc.**

The liquid nitrogen tank and accessory equipment and installations are, after completion, to be subjected to the low temperature test using liquid nitrogen. In case where thermal insulation by means of vacuum insulation is employed, an additional test to verify the vacuum insulation performance is to be conducted in parallel with the low temperature test or separately.

### **8.5 Tests and Inspection**

#### **8.5.1 Tests and Inspection**

The inert gas storage system is to be subjected to the tests specified in **8.3.1-1** and **-2**, **8.4.1(1)** and **(2)**, and **8.4.8**, and in addition to the requirements in **8.2.5** in a corresponding manner.

## **Chapter 9      LEVEL INDICATORS AND LEVEL ALARMS**

### **9.1      General**

#### **9.1.1      Application**

**1**    Level gauges for measuring fuel liquid levels in fuel containment systems and process pressure vessels, and liquid levels in nitrogen tanks are to be in accordance with the requirements in **Chapter 4, Part 7 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

**2**    Level alarm systems for detecting one or more of specific fuel liquid levels in fuel containment systems and process pressure vessels are to be in accordance with requirements in **Chapter 4, Part 7 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**: relevant requirements are to be applied mutatis mutandis.

## Chapter 10 PRESSURE GAUGES

### 10.1 General

#### 10.1.1 Application

The requirements in this chapter apply to systems for measuring fuel liquid or vapour pressures or atmospheric pressures in fuel containment systems and process pressure vessels in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### 10.2 Bourdon Tube Pressure Gauges

#### 10.2.1 Materials, Construction and Performance

- 1 Materials used for the parts of Bourdon tube pressure gauges which may possibly come in contact with fuel liquids or vapours are to be suitable for the properties of the relevant fuel.
- 2 Materials used for the parts of Bourdon tube pressure gauges which are exposed to low temperatures are to be suitable for the service temperature and other service conditions.
- 3 Construction, materials, performance and test procedures for Bourdon tube pressure gauges are to comply with *JIS B 7505* “Bourdon Tube Pressure Gauges” or other standards deemed appropriate by the Society.
- 4 Indication errors for Bourdon tube pressure gauges are to be within  $\pm 1.0\%$  of maximum measured pressure. In cases where the pressures of vacuum parts are indicated by the same gauge, the indication error is to be within  $\pm 1.0\%$  of the sum of the maximum pressure of the vacuum part and the maximum measured pressure of the gauge.
- 5 Bourdon tube pressure gauges are to be so arranged as not to be affected by mechanical external loads caused by waves or others and are to be provided with protective coverings as needed.

### 10.3 Other Types of Pressure Gauges

#### 10.3.1 Materials, Construction and Performance

- 1 Materials used for the parts of pressure sensors which may possibly come in contact with the fuel liquids or vapours, and those which are exposed to low temperatures are to be *mutatis mutandis* in accordance with the requirements in **-1** and **-2** of **10.2.1**.
- 2 Pressure sensors are, in principle, to be verified to have good performance through the tests specified in the following **(1)** to **(6)**. Some of the tests, however, may be omitted depending upon condition such as sensor type and installation location, etc.

**(1) Calibration tests:**

Apply and raise pressure from zero to the maximum pressure, and hold for 30 *minutes*, and then, reduce the pressure back to zero. During the process of raising and reducing the pressure, pressure indications at maximum pressure and three or more other graduations, as appropriate, are to be taken, and it is to be verified that the indication error falls within  $\pm 1.0\%$  of maximum measured pressure. In cases where the pressures of vacuum parts are indicated by the same gauge, the indication error is to be within  $\pm 1.0\%$  of the sum of the maximum pressure of the vacuum part and the maximum measured pressure of the gauge.

**(2) Static pressure tests:**

The indication errors  $\Delta P_1$  (the maximum pressure reached first) and  $\Delta P_2$  (after keeping the

pressure in a range from 90 to 100% of the maximum pressure for a continuous period of 5 *hours*) are to be calculated and verified to be in accordance with the following requirements:

- (a)  $\Delta P_1$  and  $\Delta P_2$  are to be within the allowable limit given in (1) above.
- (b) The absolute value of the difference between  $\Delta P_1$  and  $\Delta P_2$  is to be within the absolute value of the allowable limit given in (1) above.
- (c) There is to be no leakage.

(3) Impact tests:

Impact tests are, in principle, to be conducted using the method specified in *JIS C 0912* “Impact Test Method for Small Electric Appliances”, and an impact with a magnitude of 50*G* (490 *m/sec*<sup>2</sup>) is to be applied twice in two axial directions, including the longitudinal direction, respectively whereby it is to be verified that there are no abnormalities such as line open faults, short circuits or loose connections.

(4) Vibration-proof tests:

Vertical sinusoidal vibrations with frequencies of 1500 *cycles/min* and approximate amplitudes of  $\pm 0.3$  *mm* are to be applied for 24 *hours* to pressure measuring system with approximately half the maximum pressure being applied. Such systems are to pass the indication tests given in (1) above, and there are to be no abnormalities such as loose screws, pins or other functional faults. Furthermore, the amplitude of pressure indication during such tests is to be not more than 3 times the absolute value of allowable error.

(5) Other tests as deemed necessary by the Society depending upon sensor types.

(6) Test conditions are to be in accordance with the following:

- (a) Tests are, in principle, to be conducted at the *Class 3* standard temperature condition of  $20 \pm 5^\circ\text{C}$  specified in *JIS Z 8703*.
- (b) Tests of pressure gauges provided with zero adjusting devices are to be conducted after making zero adjustment.
- (c) Corrections are to be made only for differences in the test in cases where there is a difference between the pressure applied to the pressure measuring system and the pressure to be measured.
- (d) Calibration tests of pressure gauges are, in principle, to be conducted using standard weight type pressure gauges or standard liquid column type pressure gauges.
- (e) In cases where test pressures do not reach the maximum vacuum graduation due to low atmospheric pressures during calibration tests of vacuum gauges and compound gauges, tests are to be conducted at pressures as close as practicable to the desired graduation.
- (f) When the test period exceeds 8 *hours*, the period may be divided into 8-*hour* periods for test purposes.

**3** The requirements in **10.2.1-5** are to be applied *mutatis mutandis* for the tests of pressure gauges other than Bourbon test pressure gauges.

## **10.4 Pressure Gauges for Low Temperature Service**

### **10.4.1 General**

In addition to the tests specified in **10.2.1-2** and **10.3.1-2**, pressure gauges used at temperatures lower than  $-55^\circ\text{C}$  are to be subject to approximately 2/3 of the maximum measuring pressure at service temperature and left alone for approximately 30 *minutes*. Calibration tests are then to be carried out at this temperature and passed. The maximum test pressure used for calibration tests, however, may be approximately 2/3 of maximum test pressure.



## **10.5 Electrical Installations**

### **10.5.1 General**

**1** Electrical installations used for pressure gauges are to be in accordance with relevant chapters of **Part H** and **Part GF of the Rules**.

**2** Tests specified in **Chapter 1, Part 7 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** are to be carried out mutatis mutandis and passed.

## **10.6 Tests and Inspections**

### **10.6.1 General**

**1** Prior to installation of pressure gauges on board ship, documents proving that the same type or a similar type of the pressure gauge satisfies the performance requirements specified in **10.2.1-2** or **10.3.1-2** as well as **10.4.1** and **10.5.1-2** are to be submitted to the Society for verification. Performance verification tests carried out in the presence of a Society surveyor may be requested where deemed necessary by the Society.

**2** Tests and inspections of pressure gauges, excluding those specified in **Part H of the Rules**, carried out at manufacturing plants may be substituted by the inspections carried out by designated organizations or groups, or by manufacturers themselves.

## Chapter 11 TEMPERATURE INDICATING DEVICES

### 11.1 General

#### 11.1.1 Application

The requirements in this chapter apply to devices for measuring and indicating the temperatures of the fuel liquids or vapours in fuel containment systems and process pressure vessels in accordance with the requirements in **1.1.3-1, Part GF of the Rules** except for glass bar thermometers.

### 11.2 Materials

#### 11.2.1 General

**1** Materials used for the parts of temperature indicating devices which may possibly come in contact with fuel liquids or vapours are to be suitable for the properties of the relevant fuel.

**2** Materials used for the parts of temperature indicating devices which are exposed to low temperatures are to be suitable for the service temperature and other service conditions.

### 11.3 Temperature Measuring Sensors

#### 11.3.1 General

**1** Thermocouples used for temperature measuring are to comply with *JIS C 1602* “Thermocouples” or other standards deemed appropriate by the Society.

**2** Resistance bulbs used for temperature measuring are to comply with *JIS C 1604* “Resistance Bulbs”, *JIS F 9703* “Marine Platinum Resistance Bulbs” or other standards deemed appropriate by the Society.

**3** Thermistor bulbs used for temperature measuring are to comply with *JIS C 1611* “Thermistor Bulbs” or other standards deemed appropriate by the Society.

**4** Mercury thermometers used for temperature measuring are to comply with *JIS B 7528* “Mercury Filled Pressure Type Temperature Indicating Devices” or other standards deemed appropriate by the Society.

**5** Temperature measuring sensors other than those specified in **-1** to **-4** above are to be subject to tests based upon standards deemed appropriate by the Society or to tests depending upon operating principle and construction deemed necessary by the Society in order to verify satisfactory performance.

### 11.4 Electrical Installations

#### 11.4.1 General

**1** Electrical installations used for temperature indicating devices are to be in accordance with relevant requirements in **Part H** and **Part GF of the Rules**.

**2** Tests specified in **Chapter 1, Part 7 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** are to be carried out mutatis mutandis and passed.

## **11.5 Sensor Protectors**

### **11.5.1 General**

**1** In cases where sensors for temperature measurements are contained in airtight protective sleeves, the construction of the protective sleeves exposed to the internal pressures of tanks is to be capable of sufficiently withstanding maximum internal pressures of tanks acting as external pressures on the protective sleeves.

**2** The requirements in **11.2.1-1** are to be applied mutatis mutandis to the materials of the protective sleeves referred to in **-1** above.

**3** The protective sleeves referred to in **-1** above are to be so supported that they sufficiently withstand loads imposed in association with ship motion and movement of fuel liquids.

## **11.6 Tests and Inspections**

### **11.6.1 General**

**1** Prior to installation of temperature indicating devices on board ship, documents proving the same or a similar type of the temperature indicating devices satisfies the performance requirements specified in **11.3** and **11.4.1-2** are to be submitted to the Society for verification. Performance verification tests in the presence of a Society surveyor may be requested where deemed necessary by the Society.

**2** Tests and inspections of temperature indicating devices, excluding those specified in **Part H of the Rules**, carried out at manufacturing plants may be substituted by the inspections carried out by designated organizations or groups, or by manufacturers themselves.

**3** The protective sleeves specified in the **11.5** are to be subjected to pressure tests deemed appropriate by the Society after manufacture or be fitted to fuel tanks during hydraulic tests to verify that sleeves are free from abnormalities.

**4** The welds of the protective sleeves specified in the **11.5** are to be subjected to non-destructive tests which correspond to the non-destructive tests required for the fuel tanks in which they are to be fitted.

## **Chapter 12     INSULATION MATERIALS**

### **12.1     General**

#### **12.1.1     Application**

**1** The requirements in this Chapter apply to the insulation materials used in the fuel containment systems in accordance with the requirements in **1.1.3-1, Part GF of the Rules** or **GF6.4.13-1(1) of the Guidance**.

**2** For the insulation materials applied to the cargo piping systems, the requirements in this Chapter are to apply correspondingly.

### **12.2     Insulation Application Procedures**

#### **12.2.1     General**

**1** For the approval application of insulation materials, in addition to those general procedures, all precautions at time of application and test items are to be specified.

**2** In the application of insulation materials in each ship, detailed application procedures for each ship are to be submitted to the Society for approval.

### **12.3     Tests and Inspection**

#### **12.3.1     Tests and Inspection**

By using the test specimens taken with due regard paid to the actual application procedures, tests to verify the test items given in **Table 12.1** are to be conducted by the test procedure as specified in the same Table or suitable other procedure as approved by the Society, and it is to be verified that the specifications and physical properties established by the manufacturer are complied with.

Table 12.1 Test Items for Insulation Materials

No.	Test item	Procedure of test
1	Compatibility with the cargo	Tensile, compression, shearing, bending test after dipping in the cargo
2	Solubility in the cargo	Changes in the size and weight of test specimen before and after dipping in the cargo
3	Absorption of the cargo	Comparison of weight of test specimen or test of water absorbing properties before and after dipping in the cargo
4	Shrinkage	<i>ASTM D 2126</i>
5	Aging	<i>ASTM D 576</i> (Comparison of thermal conductivity before and after aging)
6	Closed cell content	<i>ASTM D 2856</i>
7	Density	<i>ASTM D 1622</i>
8	Mechanical properties • Bending strength • Compression strength • Tensile strength • Shearing strength	<i>ASTM C 203, D790</i> <i>ASTM D 1621</i> <i>ASTM D 1623</i> <i>ASTM C 273</i>
9	Thermal expansion	<i>ASTM D 696</i>
10	Abrasion	-
11	Cohesion	-
12	Thermal conductivity	<i>JIS A 1412, ASTM C 518</i>
13	Resistance to vibration	-
14	Resistance to fire and flame spread	<i>JIS A 9514, JIS A 9511, DIN 4102</i>
15	Resistance to fatigue failure and crack propagation	-

Note:

Of those test items given above, necessary items are to be selected and tested depending on the insulation system. However, at least, the test items 4, 6 (for independent foam material only), 7, 8, 12 and 14 are to be dealt with for all the insulation systems. See **GF6.4.13-1** to **-4**.

## **Chapter 14     OXYGEN CONTENT MEASURING EQUIPMENT**

### **14.1     General**

#### **14.1.1     Application**

The requirements in this chapter apply to the fixed-type and portable-type oxygen content measuring equipment used for the purpose of verifying whether oxygen content is less than the limits in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### **14.2     Materials, Construction and Performance**

#### **14.2.1     Materials**

Materials used for measuring equipment are to be corrosion-resistant or to be subjected to corrosion-resisting processing. Parts likely to be exposed to fuel vapour are, in particular, to be suitable for use in the atmosphere of such vapours.

#### **14.2.2     Construction**

- 1** Measuring equipment is to be provided with indicating devices capable of clearly showing that the equipment is in service when it is in operation.
- 2** Measuring equipment used in flammable atmospheres is to have the necessary explosion proof performance.
- 3** The capacities of suction pumps of measuring equipment are to be capable of drawing in detecting air in a volume sufficient for detection and measurement.
- 4** Sampling heads are to be located in consideration of the properties of the oxygen.
- 5** Sampling lines from sampling heads to measuring devices are to be independent of each other.
- 6** Measuring equipment is to be provided with a function for displaying the locations of the sampling head through which detection is being carried out and identifying the sampling location for which alarms are issued during detection.
- 7** Measuring equipment serving only to a single sampling point and portable-type measuring equipment are not subject to **-5** and **-6** above.

#### **14.2.3     Oxygen Content Indicating Parts**

Equipment is to be capable of indicating oxygen content in percent volume.

#### **14.2.4     Alarm Systems**

- 1** Measuring equipment is to be provided with audible and visual alarm systems capable of issuing alarms when setting values are exceeded.
- 2** Setting values of alarms are to be changeable as necessary, and are to be readily recognizable.
- 3** Alarm set points are to be not more than 5% (volume), except when specified otherwise.
- 4** Alarm systems are to be in accordance with the following **(1)** to **(4)**:
  - (1)** Alarms are to continue until reset even when oxygen concentrations reach values lower than the alarm setting values.
  - (2)** Audible alarms are to be arranged so that they can be temporary stopped.
  - (3)** Alarms are to resume when the gas concentrations of other sampling points exceed alarm setting values even when audible alarms are temporarily stopped.
  - (4)** Alarm systems are to be capable of issuing alarms in the event of system failures of equipment such as loss of power supply and line open failures. Visual alarms issued in such events are to

be capable of being distinguished from those issued in the cases given in -1 above.

**5** Alarm functions need not be provided for portable equipment, but means are to be provided to verify the effectiveness of batteries.

#### **14.2.5 Performance**

**1** Measuring equipment is to be capable of functioning in the anticipated environmental conditions, including varying temperature and humidity, vibrations and ship motion which normally occur on board ship.

**2** The indicating accuracy and alarming accuracy of suction-type measuring equipment are not to be significantly affected by differences of temperature or humidity between sampling heads and measuring equipment, or means are to be provided to compensate or correct for such differences.

**3** Measuring equipment is to be capable of becoming rapidly ready for detection after the power supply switch is turned on.

**4** Measuring equipment is to be capable of indicating oxygen content with an error within  $\pm 0.7\%$  (volume). In cases where detection of oxygen content less than 5% is required, however, the performance is to be such that the error is within  $\pm 20\%$  of the maximum allowable oxygen content.

**5** The equipment is to be capable of issuing alarms with errors within  $\pm 20\%$  of alarm set values.

### **14.3 Marking, Maintenance and Inspections**

#### **14.3.1 General**

**1** Measuring equipment is to be marked with the items specified in the following **(1)** to **(5)**:

- (1) name of manufacturer, date of manufacture and type number;
- (2) explosion-proof type and capability in cases of explosion-proof construction;
- (3) type of detectable gas and measuring range;
- (4) rated voltage and frequency (or type and number of batteries); and
- (5) alarm setting values.

**2** Measuring equipment is to be provided with instruction manuals as well as correction tables or equations for temperature corrections in cases where necessary.

**3** Details of periodical inspections and maintenance checks necessary for maintaining measuring equipment performance are to be clearly noted in the instruction manual. Furthermore, record books for periodical inspections and maintenance checks as well as necessary test gases and associated fittings are to be provided.

### **14.4 Tests and Inspections**

#### **14.4.1 Approval Tests**

Portable-type oxygen content measuring equipment is to pass the tests specified in **14.4.4** for each type.

#### **14.4.2 Approval of Use Tests**

Fixed-type oxygen content measuring equipment is to pass the tests specified in **14.4.4** for each type. Such tests, however, are not required in cases where the tests are carried out for individual equipment.

#### **14.4.3 Shipboard Inspections**

Operating tests of fixed-type oxygen content measuring equipment are to be carried out after the completion of installation of all piping systems and accessories on board the ship. During such

tests, at least the test gas is to be drawn from each sampling header, and alarms are to be verified.

#### **14.4.4 Test Standards**

##### **1 Visual inspections**

Visual inspections are to verify that the construction, materials and dimensions are as specified on drawings and specifications.

##### **2 Performance tests**

The following tests specified in **(1)** to **(7)** are to be carried out. Oxygen concentrations of the test gases used during tests are to be analysed by gas chromatography, etc.

###### **(1) Indicating accuracy verification**

It is to be verified that the indicating accuracy at a 5% oxygen concentration satisfies that indicated on the specification sheet.

###### **(2) Alarming accuracy verification**

It is to be verified that the oxygen concentration when alarms are issued is within the allowable range of error by gradually increasing vapour concentration.

###### **(3) Reproducibility verification**

The tests identical to **(1)** and **(2)** above are to be carried out by drawing gas and nitrogen repeatedly and alternately at appropriate intervals. In the case of portable-type equipment, connecting and disconnecting the power supply are to be included as part of the tests.

###### **(4) Response performance verification**

The period before the indication of gas concentration reaches 90% of the value of final indication is to be measured by introducing the test gas. Furthermore, test gases whose concentrations correspond to 110% of alarm setting values are to be introduced and the periods before alarms are issued are to be measured. Such periods are to be not more than 30 *seconds* in the case of fixed-type equipment and not more than 20 *seconds* in the case of portable-type equipment.

###### **(5) Alarm system operation verification**

It is to be verified that alarm systems function properly for each cause of alarm.

###### **(6) Operation initiation verification**

The tests specified in **(2)** above are to be carried out after the period of times designated on the specification sheets of measuring equipment have elapsed after the equipment had been placed in normal operation once, shut down and then restarted after 24 *hours* have passed.

###### **(7) Suction pump capacity verification**

It is to be verified that capacities of suction pumps satisfy their specifications.

##### **3 Environmental tests**

**(1)** Measuring equipment is to pass the tests specified in **(1)** and **(2)** of -2 above under the environment conditions given in the following **(a)** to **(d)**. In the case of fixed-type oxygen content measuring equipment, however, the following **(b)** may be omitted:

(a) psychrometric tests,

(b) drop tests,

(c) vibration tests,

(d) incline tests, and

(e) power supply variation tests.

**(2)** The test procedures for each test are, in principle, to be in accordance with the following:

###### **(a) Psychrometric tests**

Measuring equipment is to be placed in thermostatic tanks whose environmental conditions are adjusted to a humidity of 90-95% and a temperature of  $50 \pm 2^\circ\text{C}$ , and then left for 8 *hours*. Temperatures of thermostatic tanks are then to be adjusted to  $-10 \pm 2^\circ\text{C}$  with humidity left unadjusted, and left for another 8 *hours*. This cycle is to be repeated 3 times.



(b) Drop tests

The outer protective casings of gas detection equipment are to be removed, except in cases where the casings are fitted during use, and test object are to be dropped from a height of 100 *mm* freely in each direction, except for the sides where lenses and glass, etc. are fitted, onto a 50 *mm* thick sheet of cedar laid on top of a concrete floor.

(c) Vibration tests

Measurement equipment is to be fixed to a vibration test machine, and vibrations whose frequencies range from 5 to 16 *Hz* (double amplitude: 2 *mm*) and from 16 to 60 *Hz* (acceleration: 1*G*) are to be applied in the vertical, horizontal transverse and longitudinal directions for 30 *minutes* in each direction so that tests are to progress from low vibrations to high vibrations and then again from low to high in 10-*minute* cycles. For the fixed-type equipment, however, the tests are to be in accordance with *JIS F 8076* “Electrical installation in ships-Part 504: Special feature-Control and instrumentation”.

(d) Incline tests

Tests are to be in accordance with *JIS F 8076*.

(e) Power supply variation tests

Tests are to be in accordance with *JIS F 8076*.

4 Explosion-proof performance tests

Tests are to be in accordance with **H2.16, Part H of the Guidance**.

## **Chapter 15 HUMIDITY MEASURING EQUIPMENT**

### **15.1 General**

#### **15.1.1 Application**

The requirements in this chapter apply to fixed-type and portable-type humidity measuring equipment used as dew point meters for the purpose of verifying whether humidity concerned is less than the limits in **1.1.3-1, Part GF of the Rules**.

### **15.2 Materials, Construction and Performance**

#### **15.2.1 Materials**

Materials are to be in accordance with the requirements in **14.2.1**.

#### **15.2.2 Construction**

Construction is to be in accordance with the requirements in the **14.2.2**.

#### **15.2.3 Temperature Indicating Parts**

The equipment is to be capable of indicating humidity in terms of dew point (°C) or some suitable other method. Equipment without dew point indications is to be provided with tables for converting values into dew point values.

#### **15.2.4 Alarm Systems**

**1** The equipment is to be capable of issuing alarms or giving readily identifiable visual signals, even in the event of power supply loss, disconnected wiring, etc., or measuring equipment malfunction.

**2** The equipment is to be capable of issuing alarms when the humidity (or dew point) exceeds preset values.

#### **15.2.5 Performance**

**1** Performance is to be in accordance with the requirements in **-1 to -3 of 14.2.5** in replacing the terms “oxygen” and “oxygen concentration” therein by the terms “air (where the humidity is controlled)” and “humidity” respectively (hereinafter the same).

**2** The equipment is to be capable of indicating dew points with errors within  $\pm 5^{\circ}\text{C}$  and issuing alarms.

### **15.3 Marking, Maintenance and Inspections**

#### **15.3.1 General**

The requirements in **14.3** are to be applied mutatis mutandis.

### **15.4 Tests and Inspections**

#### **15.4.1 General**

The requirements in **14.4** are to be applied mutatis mutandis.

## Chapter 16      **FIXED DRY CHEMICAL FIRE-EXTINGUISHING EQUIPMENT**

### **16.1      General**

#### **16.1.1      Application**

**1**    The requirements in this chapter apply to fixed dry chemical fire-extinguishing equipment in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

**2**    Fixed dry chemical fire-extinguishing systems specified in **11.6.1-1, Part GF of the Rules**, are to conform to the requirements in **11.6.1-1, Part GF of the Rules**, and in addition they are to comply with the “*Guidelines for the approval of fixed dry chemical powder fire-extinguishing systems for the protection of ships carrying liquefied gases in bulk*” (MSC.1/Circ.1315).

## **Chapter 17     WATER SPRAY SYSTEM**

### **17.1     General**

#### **17.1.1     Application**

The requirements in this Chapter apply to the water spray system in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### **17.2     Submission of Plans and Documents**

#### **17.2.1     Plans and Documents for Reference**

In addition to those specified in **1.2(2)**, the following **(1)** and **(2)** are to be submitted:

- (1) Data on the capacity of nozzle
- (2) General piping and installation procedures

### **17.3     Materials, Construction and Performance**

#### **17.3.1     Materials**

The nozzles, pipes and stop valves forming the equipment are to be made of the corrosion resistant and fire resistant materials.

#### **17.3.2     Construction**

The water spray angle of the water spray system is to be 120° or below as standard.

#### **17.3.3     Performance**

- 1** The water spraying capacity of the system is to satisfy the requirements in **11.5.1, Part GF of the Rules**. Further, the minimum required pressure is to be noted in the specification.
- 2** The capacity of the pump used for water spraying is to be determined on the basis of the quantity of sprayed water from each nozzle at the assumed working pressure.

### **17.4     Marking, etc.**

#### **17.4.1     Specifications and Marking**

Water spraying capacity, working pressure (maximum and minimum), installed height (maximum and minimum), intervals of installation and where necessary, the water spraying direction are to be specified in the specification or work procedure.

### **17.5     Tests and Inspection**

#### **17.5.1     Approval Tests for Nozzles**

##### **1     Salt water spraying test**

To be in accordance with the requirements in *JIS Z2371* or other standard as deemed appropriate by the Society. However, when the materials are considered to be sufficiently corrosion-resistant, the test may be omitted.

**2 Fire resisting test**

The nozzle is to be heated in a test oven at a temperature of 704 °C or more for 10 *minutes* or more and then submerged in water where no abnormality is to be caused.

**3 Pressure test**

Water is to be sprayed at a pressure twice the maximum working pressure, and it is to be verified that no abnormality is caused.

**4 Quantity of water spray test**

Water is to be sprayed at the maximum and minimum working pressures whereby it is to be verified that the total quantity of water spray is as given in the specification.

**5 Water spray distribution test**

According to the working procedure (at the maximum and minimum heights of installation, in the direction of spray) described in the specification, the maximum and minimum working pressures are to be applied to the installed nozzle to cause water spray. In this case, the amount of water to all areas within the effective water spray surface described in the specification is as given in the specification.

**17.5.2 Shipboard Inspection**

With all fittings attached, actual water spray is to be caused and the effectiveness is to be verified. Where necessary, pressure is to be measured with a pressure gauge.

## **Chapter 19      MECHANICAL VENTILATION SYSTEMS**

### **19.1      General**

#### **19.1.1      Application**

The requirements in this chapter apply to fixed-type or portable-type mechanical ventilation systems serving spaces containing gas sources in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### **19.2      Materials, Construction and Strength**

#### **19.2.1      Materials**

Materials of component parts are to be corrosion-resistant, and those parts which are likely to come in contact with fuel vapours are to be suitable for use in the atmosphere of such vapours.

#### **19.2.2      Construction and Strength**

- 1** Systems are to be of non-sparking construction. (*See 13.3.3, Part GF of the Rules*)
- 2** Systems are to possess sufficient strength against vibrations caused by the rotation of ventilation fans.
- 3** Systems are to be provided with necessary spare parts.

### **19.3      Markings, etc.**

#### **19.3.1      Markings**

Systems are to be marked with the following items:

- (1) Name of manufacturer, date of manufacture and type number
- (2) Capacity (air flow rate, rotational speed, driving power, etc.)

### **19.4      Tests and Inspections**

#### **19.4.1      Approval Tests**

- 1** Visual inspections
- 2** Performance tests (to be in accordance with *JIS B 8330*)
- 3** Hydraulic tests are to be carried out on the pressure-bearing parts of hydraulically operated ventilation fans at test pressures 1.5 times the working pressures of such parts.

## **Chapter 20 FUEL HOSES**

### **20.1 General**

#### **20.1.1 Application**

The requirements in this chapter apply to fuel hoses used for fuel transfer in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

### **20.2 Submission of Plans and Documents**

#### **20.2.1 Plans and Documents for Reference**

In addition to those specified in the **1.2(2)**, the following **(1)** to **(4)** are to be submitted:

- (1)** Specifications including at least the following:
  - (a) hose dimensions (inside diameters, outside diameters, wall thicknesses, pitch, etc.);
  - (b) bursting pressures and rated maximum working pressures,
  - (c) maximum and minimum service temperatures;
  - (d) allowable bend radius;
  - (e) maximum lengths of manufacture;
  - (f) materials; and
  - (g) list of compatible fuels.
- (2)** Data on compatibility of the fuels and materials used
- (3)** Data on manufacturing process and quality control
- (4)** Test and inspection plans

### **20.3 Materials, Construction and Strength**

#### **20.3.1 Materials**

Materials of fuel hoses are to be compatible with the fuels intended to be used and suitable for the service temperature.

#### **20.3.2 Construction and Strength**

- 1** Fuel hoses are to be so designed to withstand at least 200 passes of cyclic pressure tests over a range zero to at least twice their rated maximum working pressure.
- 2** Fuel hoses are to be designed for bursting pressures not less than 5 times rated maximum working pressures.
- 3** Rated maximum working pressures of fuel hoses are to be 1.0 *MPa* or more.

### **20.4 Markings, etc.**

#### **20.4.1 Marking and List of Particulars**

- 1** Fuel hoses are to be marked with the items specified in the following **(1)** to **(3)**:
  - (1)** Name of manufacturer, type, date of manufacture and tested date
  - (2)** Rated maximum working pressure
  - (3)** Maximum and minimum service temperatures
- 2** Lists of particulars showing fuel hose specifications are to be attached to hoses when shipped.

## 20.5 Tests and Inspections

### 20.5.1 Approval of Use Tests

**1** Fuel hoses intended for Approval of Use are, in principle, to be subjected to the prototype tests in -2 for each type and hose bore.

**2** Prototype test methods are to be in accordance with the following **(1)** to **(6)**:

- (1) Hoses are to be subjected to at least 200 passes of cyclic pressure tests over a range from zero to at least twice the rated maximum working pressure at normal ambient temperature and with hose ends fitted.
- (2) Hoses in the state of being bent to the allowable bend radius with hose ends fitted are to be subjected to pressures corresponding to at least 1.5 times the rated maximum working pressure at normal ambient temperature.
- (3) Hoses in the straight condition with hose ends fitted are to be subjected to pressures corresponding to at least 5 times the rated maximum working pressure at upper and lower extreme service temperatures.
- (4) In applying the requirements **(1)** to **(3)** above, the pressure is to be retained for a period of at least 5 *minutes*.
- (5) Hose lengths, not including end fittings, for prototype tests are to be approximately 1.5 or more times the allowable bend radius.
- (6) In cases where the test procedures given above are difficult to follow, they may be substituted by other test procedures that are in accordance with **8.3.2, Part GF of the Rules** and are deemed appropriate by the Society.

**3** Hoses subjected to prototype tests are not to be used in actual loading/unloading.

### 20.5.2 Product Inspections

Hoses which have received Approval of Use are to be subjected to the tests specified in the following **(1)** to **(3)**, and inspections are to be carried out in the presence of a Society surveyor before being shipped.

- (1) Dimensional inspections are to verify each part of a hose is as given on relevant drawings.
- (2) Visual inspections are to verify hoses are free from any defects or deformation.
- (3) Hydraulic tests are to be carried out at nominal ambient temperature at pressures corresponding to 1.5 or more times the rated maximum working pressure and 2/5 or less than bursting pressure.



## **Chapter 21      REMOVABLE FUEL HANDLING EQUIPMENT**

### **21.1      General**

#### **21.1.1      Application**

**1** The requirements in this chapter apply to removable liquefaction pumps, heat exchangers and associated piping systems (hereinafter referred to as “removable equipment”) which are temporarily placed or installed on board ships using low-flashpoint fuels for operations of a specific purpose.

**2** All the requirements in **Part GF of the Rules** and **Part GF of the Guidance** as well as relevant requirements in this annex related to fixed equipment for handling fuel liquids or vapours, piping systems and electrical installations apply to the similar equipment and fittings forming removable equipment.

### **21.2      Submission of Plans and Documents**

#### **21.2.1      Plans and Documents for Approval**

Notwithstanding the requirements in **1.2**, the plans and documents for removable equipment given in the following **(1)** to **(11)** are to be submitted to the Society for approval.

- (1) General arrangements (including the arrangement of instruments such as thermometers and pressure gauges)
- (2) Diagrams of fuel piping systems (including design pressures, design temperatures and the material specifications)
- (3) Structural diagrams of fuel heaters including fittings
- (4) Structural diagrams of fuel pumps and their prime movers
- (5) Detailed diagram of fuel hoses
- (6) Plans for equipment and fuel piping earthing
- (7) Plans of cable installations
- (8) Diagrams of wiring systems
- (9) Installation, operation and removal procedure manuals (hereinafter referred to as “procedure manual”)
- (10) Installation plans
- (11) Other data and documents deemed necessary by the Society

#### **21.2.2      Procedure Manuals**

**1** Procedure manuals are to be finalized before approval after making necessary additions, deletions and modifications based upon the results of the tests and inspections specified in **21.5**.

**2** Procedure manuals are to consist of at least the following items:

- (1) equipment particulars,
- (2) installation and removal procedures and check lists,
- (3) operation procedure and check lists,
- (4) periodical maintenance and inspection procedures,
- (5) equipment and fitting (including fuel hoses) certificates,
- (6) installation and removal records,
- (7) operational records, and
- (8) maintenance and inspection records

## 21.3 Construction and Installation

### 21.3.1 General

- 1 The construction, installation and arrangement of the component equipment, piping systems and electrical installations forming removable equipment are to be in accordance with the relevant requirements of **the Rules and Guidance** referred to in this chapter in effect at the time of application for approval, regardless of the the age of the ship where the removable equipment is intended to be installed.
- 2 Removable equipment is not to be installed within non-hazardous areas.
- 3 Main component equipment forming removable equipment such as fuel pumps and prime movers, etc. are, in principle, to be fixed on a rigid foundation of integral construction and the entire assembly, including the piping systems, is to be unitized.
- 4 Hull structures of ships where removable equipment is installed are to be suitably reinforced and permanent foundations for installation are to be provided.
- 5 Bed plates and installation mounts of removable equipment are to be connected firmly by anchor bolts.

### 21.3.2 Fuel Piping Systems

- 1 Fuel pumps or fuel heaters used in removable equipment are not to be directly connected to the fuel lines or fuel hoses of shore installations.
- 2 It is recommended that the discharge sides of fuel pumps used in removable equipment be connected to existing permanent piping systems of the ship and that fuel be transferred through the fixed shore-connections.
- 3 In cases where the shore-connections referred to in -2 above are not used, removable equipment is to be provided with a dedicated shore-connection assembly which includes the emergency shutoff valves specified in **5.5.3, Part N of the Rules**. Sufficient consideration is to be given to such shore-connection assemblies so as to avoid any risk of damage to fuel pumps and emergency shutoff valves during fuel hose connecting and disconnecting operations.
- 4 Means are to be provided for the protection of the hull structure and prevention of undue spillage of fuel beneath any areas where fuel leakage is likely to occur during the operation and disconnection of removable equipment.
- 5 Fuel hoses used for removable equipment are to be in accordance with the requirements in **5.7, Part N of the Rules** and **Chapter 20** of this annex.

## 21.4 Electrical Installations

### 21.4.1 Cables

- 1 Cables used for removable equipment, except those specified in -2 below or laid within steel pipes or conduits, are to be effectively supported and fixed.
- 2 In cases where the use of flexible cables in hazardous areas is unavoidable, the cables are to be in accordance with the requirements in -1 above and the following **(1)** to **(3)**:
  - (1) flexible cable length is to be as short as practicable;
  - (2) flexible cables are to be suitably reinforced or to be provided with equivalent protection; and
  - (3) electrical equipment or cable connection boxes are to be of a construction which will not cause any damage to flexible cables at cable inlets and outlets.
- 3 Power feeding cables for removable equipment are to be provided with suitable means of power shutoff and fail-safe so that no power is fed during periods when removable equipment is being removed.

4 Cable ends located at exposed areas of the ship are to be effectively protected against the ingress of seawater and rainwater during the removal of removable equipment.

## **21.5 Tests and Inspections**

### **21.5.1 Inspections During Manufacturing**

Detailed inspections during manufacturing are to be carried out on the component equipment, piping systems and electrical installations forming removable equipment to verify that their construction, materials and workmanship are in accordance with the requirements in this chapter.

### **21.5.2 Inspections of Existing Equipment**

The inspections specified in **21.5.1** are to be carried out mutatis mutandis on any existing removable equipment being installed on Society classed ships for the first time prior to installation in order to verify the removable equipment is in accordance with the requirements in this chapter.

### **21.5.3 Inspections at Installation**

**1** The tests and inspections given in the following **(1)** to **(3)** are to be carried out when removable equipment is being installed on board ships for the first time:

- (1)** Verification of installation location and installation procedure.
- (2)** Tests under operating conditions using actual fuel liquids or vapours are to be carried out to verify that there are no abnormalities and fuel leakage. In such cases, test pressures and temperatures are to be those which maintain normal operation.
- (3)** Verification of removal procedures and storage locations.

**2** In tests and inspections specified in **-1** above, it is to be verified that no abnormalities in any of the items listed in procedure manuals. Any unsatisfactory items are to be corrected accordingly and such corrections are to be verified by a Society surveyor.

**3** In cases where removable equipment which has passed the tests and inspections specified in **21.5.1** or **21.5.2** and **21.5.3-1** is removed from a ship and is intended to be reinstalled on the same ship, the tests and inspections specified in **-1** above are to be carried out mutatis mutandis in the presence of a Society surveyor at each instance of installation. The attendance of a Society surveyor, however, may be omitted on condition that installation and operation are carried out in accordance with the finalized and approved procedures specified in **-2** above, the ship master assumes responsibility for and supervises the tests, and the records specified in **-2(6)** to **(8)** of **21.2.2** are properly taken.

**4** In cases where removable equipment which has passed the tests and inspections referred to in **21.5.1** or **21.5.2** as well as **-1** above is removed from a ship and intended to be installed on another ship, the tests and inspections specified in **-1** above are to be carried out in the presence of a Society surveyor at each instance of installation. This requirement, however, may be dispensed with when an examination of the ship to which the removable equipment is to be installed determines that it is identical to the ship which had undergone the tests and inspections specified in **-1** above.

### **21.5.4 Precautions at Periodical Inspections**

Ships for which tests and inspections at the time of removable equipment installation on board were omitted in accordance with the requirements in the **-3** or **-4** of **21.5.3** are to present records of removable equipment installation and operation to Society surveyors for verification purposes during periodical surveys. In this respect, Society surveyors may order the suspension of use of such removable equipment depending upon the present condition of the ship and the removable equipment, and the results of examinations of the aforementioned records.

## **21.6 Maintenance and Inspections**

### **21.6.1 General**

- 1** Removable equipment is to be inspected, at least once a year, by the responsible personnel of the ship or shore storage facilities.
- 2** The results of the inspections referred to in **-1** above are to be entered into procedure manuals.
- 3** In cases where removable equipment is stored on board ship, such storage areas are to be located in well ventilated spaces within hazardous areas.

## **Annex 2**

## **GUIDANCE FOR GAS-FUELLED BOILERS**

### **Chapter 1      GENERAL**

#### **1.1      Scope**

**1** This annex applies to gas-only engines and dual fuel engines that are used for main boilers using natural gas (hereinafter referred to as “boiler”) and gas fuel supply systems in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

**2** Boilers and gas fuel supply systems are to be in accordance with relevant requirements in **Part D** and **Part GF of the Rules**, in addition to the requirements of this annex.

**3** The annex is also to be applied mutatis mutandis to auxiliary boilers for which the use of natural gas fuel has been approved.

#### **1.2      Equivalency**

Boilers and gas fuel supply systems not in accordance with the requirements of this annex may be accepted provided that they are deemed to be equivalent by the Society to those approved in accordance with this annex.

#### **1.3      Submission of Plans and Documents**

The plans and documents to be submitted are as follows.

(1) Plans and documents for approval

- (a) Items specified in **9.1.3, Part D of the Rules**
- (b) Items specified in **18.1.3(1), (3) and (5), Part D of the Rules**
- (c) Gas fuel burning devices
- (d) Boiler control system diagrams related to the burning of gas fuel (including monitor, safety and alarm devices)
- (e) Gas leak protection devices for connections between boilers and gas fuel supply piping systems
- (f) Gas fuel preparation plants (including construction, equipment and control system)
- (g) Gas fuel supply piping systems (including details of valves and pipe fittings) and devices to protect surrounding areas, etc. from gas leakages
- (h) Automatic control and remote control systems for gas fuel supply systems
- (i) Prototype test plans for gas fuel burning devices and test results
- (j) Onboard test plans
- (k) Sea trial plans
- (l) Other drawings and data deemed necessary by the Society depending upon the type of boiler

(2) Plans and documents for reference

- (a) Instruction manuals (including guidance for onboard maintenance, inspection and overhaul)
- (b) Other drawings and data deemed necessary by the Society

## **Chapter 2      CONSTRUCTION AND EQUIPMENT OF BOILER**

### **2.1      General**

**1** Boilers are to be of a dual-fuel engine type or gas-only engine type. In the case of dual-fuel engine types, boiler burners are to be suitable to stably burn either oil fuel alone (hereinafter referred to as “oil burning”), gas fuel alone (hereinafter referred to as “gas burning”) or oil and gas fuel simultaneously (hereinafter referred to as “oil/gas burning”).

**2** Boiler burners are to be capable of ensuring stable burning under all conditions of combustion including the following **(1)** to **(5)** according to the type of burner. In addition, they are, in principle, to be of the type that has passed the prototype tests specified in **4.1**.

**(1)** Switching from one fuel to another (switching between oil burning, oil/gas burning and gas burning in the cases of dual-fuel engines), and purging the fuel supply systems with inert gas (when oil burning is to be continued)

**(2)** Rapid load fluctuations

**(3)** Minimum load conditions

**(4)** Minimum oil fuel supply during oil/gas burning

**(5)** Other conditions as deemed necessary by the Society depending upon the type of burner

**3** Boilers of a dual-fuel engine type are to be provided with means for manually switching from gas burning to oil/gas burning or oil burning when boiler operations are unstable as well as during manoeuvring and port operations unless switching from gas burning to oil burning is carried out automatically.

**4** Boilers of a dual-fuel engine type are to be capable of being quickly switched from oil/gas burning or gas burning to oil burning.

### **2.2      Construction and Arrangement**

**1** The construction of boilers is to be such that a smooth combustion gas flow is ensured without stagnation of the gas fuel, and neither gas fuel nor combustion gases leak out of the boilers.

**2** The construction of boilers is to be capable of effective ventilation by a smooth flow of purge gas and air when the combustion chamber is ventilated. The ventilating system is to be as deemed appropriate by the Society.

**3** Uptakes of boilers are to be independent through to the funnel top and the uptakes of other combustion systems or exhaust gas pipes of other equipment are not to be connected thereto.

**4** Sufficient consideration is to be given to the temperature rise of the exhaust gases at the combustion chamber outlets of superheaters during gas burning.

**5** Combustion air intakes of boilers are to be independent and means are to be provided as deemed appropriate by the Society to ensure forced air supply.

### **2.3      Burners**

**1** Gas fuel supply pipes to burners are to be provided with manually operable shut-off valves. In addition, non-return valves and back-fire prevention devices are to be provided in a series.

**2** Gas fuel supply pipes to burners are to be purged automatically with appropriate inert gases after burners are extinguished.

**3** Gas fuel burners are to be so arranged that they can be ignited individually only by flames of oil fuel burners. In such cases, oil fuel burners are to be large enough to instantly ignite the gas fuel at any nozzle of gas fuel burners.

**4** Each burner is to be provided with at least two flame detectors. If a self-diagnostic function

capable of monitoring failures of own system as deemed appropriate by the Society is provided, however, a single detector may be accepted.

**5** When flame detectors which are not suitable to monitor a particular mode of burning are provided, a flame detector appropriate for the relevant burning mode is to be provided separately in accordance with **-4** above.

**6** Gas fuel burners are to be provided with a means to ensure the cutting off of gas fuel supplies before dismounting.

**7** Gas fuel burners are to be so arranged as not to be damaged by fire during oil burning.

**8** Fuel oil burners are to be so arranged as not to be burn-damaged when boilers are operated under the oil burning mode.

## Chapter 3      CONTROL SYSTEMS AND SAFETY SYSTEMS

### 3.1      Control Systems

#### 3.1.1      Gas Burning Control Systems

Control systems for gas fuel burning are to be in accordance with the requirements specified in the following (1) to (5), in addition to the requirements of **18.4.1** and **18.4.2, Part D of the Rules**.

- (1) It is to be so arranged that gas fuel is not supplied to burners until the flames of pilot burners used for gas fuel ignition are established and secured. In cases where gas fuel supply is initiated manually, it is to be so arranged that the gas fuel supply is cut off automatically when gas fuel supply valves are opened before flame of pilot burners are established, or that the gas fuel supply valves are locked until the pilot burner flames are established.
- (2) Control systems regulating oil/gas supply ratios are to be capable of maintaining combustion over the full range of loads approved for oil/gas burning with consideration given to ensuring sufficient supplies of combustion air.
- (3) Combustion air supplies for gas burning or oil/gas burning are to be automatically controlled to ensure safe combustion within the possible combustible range.
- (4) Combustion chambers of boilers are to be capable of automatic purging with sufficient volumes of air both before igniting base burners and after extinction of all burners. Arrangements deemed appropriate by the Society are to be made to enable boilers to be manually purged.
- (5) In the case of gas fuel supply rate control systems, it is to be so arranged that gas fuel supply rates are ensured not to be reduced less than predetermined minimum supply rates verified in advance by tests.

### 3.2      Safety Systems

#### 3.2.1      Safety Systems and Alarm Systems of Boilers

**1** Safety systems and alarm systems of boilers are to be in accordance with the following (1) to (4) requirements, in addition to the requirements of **9.9.10**, and **18.4.4** and **18.4.5, Part D of the Rules**.

- (1) Safety systems are to be provided so that gas fuel supplies to all burners are cut off to stop the operation of boilers when the following (a) to (g) occur during gas burning or oil/gas burning. The double block and bleed valves specified in **9.4.4, Part GF of the Rules** may be used as automatic cut off valves for this purpose.
  - (a) when all flame detectors specified in **2.3-4** issue flame-fail signals (in such cases, it is to be able to stop the supply within 4 *seconds* after flame-fail)
  - (b) when water level falls
  - (c) when combustion air supply stops
  - (d) when gas fuel supply pressure falls
  - (e) when the double block and bleed valves specified in **9.4.4, Part GF of the Rules** fail
  - (f) when the master gas fuel valves specified in **9.4.2, Part GF of the Rules** close
  - (g) when deemed necessary by the Society
- (2) In the event of any conditions in (d) to (f) of (1) above, automatic switching to oil burning may be substituted for stopping the boiler.
- (3) Means are to be provided to issue alarms in the following (a) and (b) cases:
  - (a) when gas fuel supply pressure falls, and
  - (b) when one of the two flame detectors specified in **2.3-4** issues a flame-fail signal.



- (4) The following **(a)** and **(b)** interlocking features are to be arranged for the starting and stopping of gas burning or oil/gas burning:
  - (a) Gas fuel supply valve are to be opened after detecting that flames of oil fuel have been established when gas burning or oil/gas burning is started.
  - (b) Regulation or closing of oil fuel supply valves is to be not effected before closing gas fuel supply valves when oil/gas burning is stopped or extinguished.
- 2 Boilers of ships subject to the **Rules for Automatic and Remote Control Systems** are to be in accordance with the requirements of **3.2** and **3.6** of said rules as well as **-1** above. In addition, such boilers are to be provided with devices which issue alarms in the event any of the abnormalities specified in the following **(1)** to **(10)** occurs:
  - (1) abnormal gas fuel temperatures;
  - (2) abnormal gas fuel supply pressures;
  - (3) abnormalities in gas fuel supply compressors;
  - (4) stopping of ventilation fans for protection ducts of the gas fuel supply piping specified in **9.5.1, Part GF of the Rules** or low inert gas pressures in space between concentric pipes;
  - (5) low inert gas supply pressures for purging gas fuel piping systems and burners;
  - (6) low pressures of hydraulic or pneumatic power sources for burning control, or loss of electric power supplies;
  - (7) activation of the double block and bleed valves specified in **9.4.4, Part GF of the Rules**;
  - (8) closing of the master gas fuel valves specified in **9.4.2, Part GF of the Rules**;
  - (9) occurrence of factors causing the detecting systems specified in **Part GF of the Rules** to activate; or
  - (10) others deemed necessary by the Society.

## Chapter 4 TESTS

### 4.1 Prototype Tests

Burners of boilers are to be subjected to prototype tests using gas fuel to demonstrate design performance in accordance with test plans approved by the Society. Such tests, however, may be substituted for by the submission of sufficient records of performance data in cases where deemed appropriate by the Society.

### 4.2 Shop Tests

- 1 Tests of boilers are to be carried out in accordance with the requirements in **9.10.1, Part D of the Rules**.
- 2 Operating tests of burners are to be conducted using the gas fuel. Shop tests using only oil fuel, however, may be accepted in cases deemed appropriate by the Society when the burners are of the same or similar type as burners which have passed the prototype tests specified in **4.1**.
- 3 The tests specified in -2 above may be substituted for with the tests specified in **4.3** in cases where deemed appropriate by the Society.

### 4.3 Tests after Installation On Board

- 1 Boilers are to be tested in accordance with the requirements of **9.10.2, Part D of the Rules**.
- 2 Automatic control systems and remote control systems for equipment handling gas fuel of boilers and gas fuel preparation plants are to be tested using gas fuel in normal service conditions before the first cargo loading.
- 3 Part or all of the tests specified in -2 above may be conducted during the sea trials specified in **4.4**.

### 4.4 Sea Trials

- 1 Performance of the control systems for boilers of dual-fuel engine type and related equipment is to be verified during operations using oil fuel in accordance with the requirements in **18.7.4-2, Part D of the Rules** and **2.2.5 of the Rules for Automatic and Remote Control Systems** depending upon their of installation characters. In addition, tests are to be carried out using gas fuel to verify the control performance of low-pressure dual fuel engines and gas-only engines mutatis mutandis in accordance with the aforementioned requirements.
- 2 The sea trials specified in **2.3.1, Part B of the Rules** are to be carried out for low-pressure dual-fuel engine types operating using oil fuel only. In addition, only the tests in **2.3.1, Part B of the Rules** deemed necessary by the Society are to be carried out during the sea trials for low-pressure dual-fuel type engines and the gas-only type engines operating by gas burning or oil/gas burning.

## **Annex 3                      GUIDANCE FOR HIGH PRESSURE GAS-FUELLED ENGINES**

### **Chapter 1              GENERAL**

#### **1.1        Scope**

**1** This annex applies to reciprocating engines designed to directly inject natural gas precompressed to a high pressure into cylinders and ignite with appropriate sources of ignition for due combustion at the termination of compression strokes (hereinafter referred to as “high pressure gas-fuelled engines”), and to gas fuel supply systems in accordance with the requirements in **1.1.3-1, Part GF of the Rules**.

**2** High pressure gas-fuelled engines and gas fuel supply systems are to be in accordance with requirements related to diesel engines and gas fuel supply system specified in **Part D** and **Part GF of the Rules**, in addition to the requirements of this annex.

#### **1.2        Equivalency**

High pressure gas-fuelled engines which do not comply with the requirements of this annex may be accepted provided that they are deemed to be equivalent by the Society to those approved in accordance with this annex.

#### **1.3        Submission of Plans and Documents**

The plans and documents to be submitted are as follows.

- (1) Plans and documents for approval
  - (a) Drawings and data specified in **2.1.3-1(1), Part D of the Rules**
  - (b) Drawings and data specified in **18.1.3(1), (2) and (3), Part D of the Rules**
  - (c) Gas fuel injection valves
  - (d) High pressure oil pipes for actuating gas fuel injection valves and associated protective shielding
  - (e) Gas fuel injection pipes and associated protective shielding
  - (f) High pressure oil pipes for sealing gas fuel injection valves and associated protective shielding
  - (g) Arrangements of gas detectors
  - (h) Combustion monitoring devices
  - (i) Gas fuel injection valve actuating devices
  - (j) Governors
  - (k) Engine control system diagrams (including monitor, safety and alarm devices) for gas fuel combustion operations
  - (l) Gas leak protective devices at connections between engines and gas fuel supply piping
  - (m) Gas fuel supply piping systems (including details of valves and pipe fittings) and protective devices for gas leaks from said systems
  - (n) Prototype test plans and test results
  - (o) Shop test plans
  - (p) Sea test plans
  - (q) Sea trial plans
  - (r) Other drawings and data as deemed necessary by the Society according to the type of high pressure gas-fuelled engine

- (2) Plans and documents for reference
  - (a) Drawings and data specified in **2.1.3-1(2), Part D of the Rules**
  - (b) Instruction manuals (including procedures for onboard maintenance, inspection and overhaul)
  - (c) Other drawings and data deemed necessary by the Society

## **Chapter 2      CONSTRUCTION AND EQUIPMENT OF HIGH PRESSURE GAS-FUELLED ENGINES**

### **2.1      General**

- 1**    High pressure gas-fuelled engines are to be dual fuel system types capable of operating on oil fuel and gas fuel, or gas-only system types.
- 2**    High pressure gas-fuelled dual fuel engines are to be capable of supplying oil fuel to each cylinder in amounts sufficient for maintaining stable combustion of gas fuel under any conditions.
- 3**    High pressure gas-fuelled engines are to be capable of maintaining stable operations even under any of the following **(1)** to **(3)** conditions:
  - (1) switching from one fuel to another (in the cases of dual fuel engines),
  - (2) rapid load fluctuations, and
  - (3) minimum load conditions during gas combustion.
- 4**    Only oil fuel is, in principle, to be used when operation of high pressure gas-fuelled dual fuel engines is unstable.
- 5**    High pressure gas-fuelled dual fuel engines are to be capable of quickly switching from gas combustion mode to oil fuel only combustion mode.

### **2.2      Construction and Strength**

#### **2.2.1      Gas Fuel Injection Valves**

- 1**    Gas fuel injection valves are to possess satisfactory operating characteristics and durability for the assumed service period.
- 2**    Gas fuel injection valves are to be provided with sealing systems to effectively prevent gas fuel from leaking through spaces around valve spindles.
- 3**    Gas fuel injection valves are to be provided with effective cooling systems.

#### **2.2.2      Gas Fuel Injection Valve Actuating Systems**

- 1**    Gas fuel injection valve actuating systems are to be reliably functional and operational.
- 2**    When operating gas fuel injection valves equipped with actuating oil piping systems and sealing oil piping systems, the high pressure sections of such systems fitted to engine bodies are to be protected from actuating oil splashing in accordance with the requirements in **2.5.4, Part D of the Rules**.
- 3**    Appropriate means are to be provided in cases where gas fuel injection valve actuating oil is required to be kept clean.

#### **2.2.3      Cylinder Covers**

- 1**    The shapes of combustion chambers and the arrangements of gas fuel injection valves and oil fuel (or pilot oil) injection valves are to be such that reliable ignition and combustion of gas fuel are ensured.
- 2**    The portions of cylinder covers where gas fuel injection valves and oil fuel injection valves are fitted are to be so constructed as to prevent leakages of gas fuels and unburnt gases into cylinders.

## 2.3 Safety Systems

### 2.3.1 Combustion Monitoring Devices

1 When high pressure gas-fuelled engines are operated on gas fuel, the items specified in the following (1) to (4) are, in principle, to be monitored and gas fuel supplies to engines are to be automatically cut off in cases where any abnormalities are detected:

- (1) gas fuel injection valve function,
- (2) pilot oil fuel injection valve function (in the case of dual fuel engines),
- (3) exhaust gas valves function, and
- (4) exhaust gas temperatures at cylinder outlets.

2 When high pressure gas-fuelled engines are operated on gas fuel, the following items are, in general, to be monitored:

- (1) abnormalities in cylinder pressure, and
- (2) blow-by through exhaust valves.

### 2.3.2 Protection Against Explosions

1 Relief valves approved in accordance with **Table D2.4, Part D of the Rules** are to be provided for crankcases.

2 Scavenge spaces and exhaust systems are to be fitted with suitable pressure relief systems unless designed to withstand the worst case overpressure due to ignited gas leaks.

3 Relief valves for cylinders installed in accordance with the requirements of **2.4.2, Part D of the Rules** are to be provided, as far as practicable, with monitoring systems to verify valve closing.

4 Engines having spaces under pistons that directly lead to crankcases are also to be in accordance with **10.3.1-2, Part GF of the Rules**.

### 2.3.3 Governors

1 Governors for high pressure gas-fuelled engines are to be capable of being operated during gas fuel combustion mode. In the case of dual fuel engines, governors are additionally to be capable of being operated either during gas and oil fuel (or pilot oil) combustion mode, and/or oil fuel only combustion mode.

2 The governors in -1 above are to be in accordance with the requirements in **2.4.1-1, Part D of the Rules** for each mode of operation.

3 Gas-fuelled dual fuel engines using high-pressured gas fuel are to be operated in any of the modes specified in the following (1) to (3):

- (1) controllable gas fuel supply and fixed oil fuel (pilot oil) supply,
- (2) controllable oil fuel (pilot oil) supply and fixed gas fuel supply, or
- (3) controllable gas fuel and oil fuel supplies.

## 2.4 Accessory Equipment

### 2.4.1 Exhaust Gas Systems

Exhaust gas pipes of high pressure gas-fuelled engines are not to be connected to the exhaust gas pipes or the exhaust pipes of other engines or systems.

### 2.4.2 Starting Systems

Starting air branch pipes to cylinders are to be provided with effective flame arresters.

### **2.4.3 Gas Fuel Pipes**

- 1** Gas fuel pipes (only those attached to engines) are to be provided with effective protective shielding against gas fuel bursting due to pipe failure.
- 2** Spaces between gas fuel pipes (only those attached to engines) and protective shielding are to be in accordance with the requirements in **9.6, Part GF of the Rules**; relevant requirements are to be applied mutatis mutandis.
- 3** Only approved type flexible tubes are to be used as protective shielding.
- 4** Gas fuel pipes are to be provided with systems for inerting and gas-freeing.
- 5** Expansion joints provided for gas fuel pipes (only those attached to engines) are to be approved in accordance with the requirements in **Annex 1** “Guidance for Equipment and Fittings of Ships Using Low-flashpoint Fuels”.

### **2.4.4 Cylinder Lubrication**

Cylinder lubricating systems for high pressure gas-fuelled engines are, in general, to be capable of maintaining adequate alkali values and cylinder oil feeding rates for oil fuel only operation as well as the modes of operation specified in **2.3.3-3(1) to (3)**.

## Chapter 3      **CONTROL SYSTEMS AND SAFETY SYSTEMS**

### **3.1      General**

**1**      Control systems for operating high pressure gas-fuelled engines using gas fuel are to be in accordance with the requirements in **18.1** to **18.3** and **18.7, Part D of the Rules**: relevant requirements are to be applied mutatis mutandis.

**2**      Temperatures and pressures of gas fuel supplied to high pressure gas-fuelled engines are to be automatically controlled. In addition, visual and audible alarm devices which activate when temperatures and pressures exceed preset ranges are to be provided.

### **3.2      High Pressure Gas-fuelled Engines of Ships Subject to the Rules for Automatic and Remote Control Systems**

High pressure gas-fuelled engines of ships subject to the application of the **Rules for Automatic and Remote Control Systems** are to be in accordance with the requirements in **3.2, 3.5, 4.1** and **4.2** of the said rules. In addition, such engines are to be in accordance with the following **(1)** and **(2)** requirements:

- (1)** High pressure gas-fuelled engines are to be provided with safety systems which automatically cut off gas fuel supply when **(a)** or **(b)** given below occur. In addition, in the case of dual fuel engines, such systems are to automatically switch the mode of operation to oil fuel only or are to stop the engines. Automatic cut off of gas fuel supplies with the double block and bleed valves specified in **9.4.4, Part GF of the Rules**, however, may be accepted.
  - (a)** When the abnormalities specified in **2.3.1-1** are detected.
  - (b)** Other cases deemed necessary by the Society.
- (2)** High pressure gas-fuelled engines are to be provided with systems which automatically reduce speed or switches the mode of operation to oil fuel only, and which issue alarms in the event any of the abnormalities specified in the following **(a)** to **(d)** occurs:
  - (a)** abnormal gas fuel temperatures;
  - (b)** abnormal gas fuel supply pressures;
  - (c)** low pressures of hydraulic pneumatic sources, or loss of electric power supplies for gas fuel combustion control, or
  - (d)** others deemed necessary by the Society.



## Chapter 4 TESTS

### 4.1 Prototype Tests

1 High pressure gas-fuelled engines are to be subjected to prototype tests using gas fuel to demonstrate design performance in accordance with prototype test plans approved by the Society. Such tests, however, may be substituted for by verification tests using one or more cylinders of a prototype engine or a similar engine in cases where deemed appropriate by the Society.

2 Parts and accessory equipment of high pressure gas-fuelled engines related to the supply and combustion of gas fuel may be required to undergo separate tests, in addition to the tests specified in -1 above, to demonstrate individual performance in cases where deemed necessary by the Society.

### 4.2 Shop Tests

#### 4.2.1 Hydraulic Tests

Pressure parts and accessory equipment with pressure parts of high pressure gas-fuelled engines are to be subjected to hydraulic tests in accordance with the requirements of **16.7.3, Part GF of the Rules** and **2.6.1, Part D of the Rules**: relevant requirements are to be applied mutatis mutandis.

#### 4.2.2 Shop Trials

1 High pressure gas-fuelled engines are, in principle, to be subjected to shop trials using fuel gas before installation on board ship. Shop trials using only oil fuel, however, may be accepted for dual fuel engines which are identical or similar to engines which have passed the prototype tests specified in 4.1.

2 Even in cases where shop trials using only oil fuel are approved in accordance with the requirements of -1 above, the operation of equipment related to the combustion of gas fuel is to be verified by appropriate means to be satisfactory as far as practicable.

### 4.3 Tests after Installation On Board

Control systems of high pressure gas-fuelled engines and related equipment are to be tested depending upon their installation characters in accordance with the requirements of **18.7.3, Part D of the Rules** or the requirements of **2.2.4 of the Rules for Automatic and Remote Control Systems**: relevant requirements are to be applied mutatis mutandis.

### 4.4 Sea Trials

1 Performance of control systems of high pressure gas-fuelled engines and related equipment is to be verified during operations using gas fuel depending upon their installation characters in accordance with the requirements of **2.2.5** or **2.2.6 of the Rules for Automatic and Remote Control Systems**: relevant requirements are to be applied mutatis mutandis.

2 The seal trials specified in **2.3.1, Part B of the Rules** are to be carried out using gas fuel only. Some of the aforementioned tests, however, may be omitted in cases where deemed to be appropriate the Society.

## Chapter 1 GENERAL

### 1.1 Scope

**1** This annex applies to reciprocating engines designed to directly inject natural gas not compressed to high pressure into cylinders during suction strokes or into suction piping and ignite for combustion at the termination of compression strokes (hereinafter referred to as “low pressure gas-fuelled engines”), and gas fuel supply systems in accordance with the requirements of **1.1.3-1, Part GF of the Rules**.

**2** Low pressure gas-fuelled engines and gas fuel supply systems are to be in accordance with requirements related to diesel engines and gas supply systems specified in **Part D** and **Part GF of the Rules**, in addition to the requirements of this annex.

### 1.2 Equivalency

Low pressure gas-fuelled engines which do not comply with the requirements of this annex may be accepted provided that they are deemed to be equivalent by the Society to those approved in accordance with this annex.

### 1.3 Submission of Plans and Documents

The plans and documents to be submitted are as follows.

- (1) Plans and documents for approval
  - (a) Drawings and data specified in **2.1.3-1(1), Part D of the Rules**
  - (b) Drawings and data specified in **18.1.3(1), (2) and (5), Part D of the Rules**
  - (c) Gas fuel injection valves and associated actuating systems
  - (d) Gas fuel injection pipes and associated protective shielding
  - (e) Arrangements of gas detectors
  - (f) Combustion monitoring devices
  - (g) Governors
  - (h) Engine control system diagrams (including monitor, safety and alarm systems) for gas fuel combustion operations
  - (i) Gas leak protection systems at connections between engines and gas fuel supply piping systems
  - (j) Gas fuel supply piping systems (including details of valves and pipe fittings) and protective devices for gas leaks from such systems
  - (k) Prototype test plans and test results
  - (l) Shop test plans
  - (m) Sea Test plans
  - (n) Sea trial plans
  - (o) Pilot oil fuel injection devices or ignition systems
  - (p) Other drawings and data deemed necessary by the Society according to the type of low pressure gas-fuelled engine
- (2) Plans and documents for reference
  - (a) Drawings and data specified in **2.1.3-1(2), Part D of the Rules**
  - (b) Instruction manuals (including procedures for onboard maintenance, inspection and

- overhaul)
- (c) Other drawings and data deemed necessary by the Society

## **Chapter 2      CONSTRUCTION AND EQUIPMENT OF LOW PRESSURE GAS-FUELLED ENGINES**

### **2.1      General**

- 1**    Low pressure gas-fuelled engines are to be dual fuel system types capable of operating on oil fuel and gas fuel, or gas-only system types.
- 2**    Low pressure gas-fuelled dual fuel engines are to be capable of supplying oil fuel to each cylinder in amounts sufficient for maintaining stable combustion of gas fuel under any conditions.
- 3**    Low pressure gas-fuelled engines are to be capable of maintaining stable operation even under any of the following **(1)** to **(3)** conditions:
  - (1) switching from one fuel to another (in the cases of dual fuel engines),
  - (2) rapid load fluctuations, and
  - (3) minimum load conditions during gas combustion.
- 4**    Gas fuel supply pressures for low pressure gas-fuelled engines are to always be kept higher than suction air pressures at the supply points of gas fuel to combustion chambers or the suction pipes before suction valves in order to prevent any back-flow of air into gas fuel lines.
- 5**    Only oil fuel is, in principle, to be used when operation of low pressure gas-fuelled dual fuel engines are unstable.
- 6**    Low pressure gas-fuelled dual fuel engines are to be capable of quickly switching from gas combustion mode to oil fuel only combustion mode.

### **2.2      Construction and Strength**

#### **2.2.1      Gas Fuel Valves and Actuating Systems**

- 1**    Gas fuel valves are to possess satisfactory operating characteristics and durability for the assumed service period.
- 2**    Gas fuel valves are to be provided with sealing systems to effectively prevent gas fuel from leaking through spaces around valve spindles.
- 3**    Actuating systems of gas fuel valves are to possess satisfactory operating characteristics and reliability.

#### **2.2.2      Cylinder Covers**

- 1**    The shapes of combustion chambers and the arrangements of gas fuel valves are to be such that reliable ignition and combustion of gas fuel are ensured.
- 2**    The portions of cylinder covers where gas fuel valves and oil fuel injection valves are fitted are to be so constructed as to prevent the leakages of gas fuels and unburnt gases into cylinders.

### **2.3      Safety Systems**

#### **2.3.1      Combustion Monitoring Devices**

- 1**    When low pressure gas-fuelled engines are operated on gas fuel, gas fuel supplies are to be automatically cut off in cases where any of the abnormalities specified in the following **(1)** to **(4)** is detected:
  - (1) gas fuel valve function,
  - (2) pilot oil fuel injection valve (in the cases of dual fuel engines) or ignition system (in the cases of gas-only engines) function,

- (3) suction valve and exhaust valve function, and
- (4) exhaust gas temperatures at cylinder outlets

2 When low pressure gas-fuelled engines are operated on gas fuel, the following items are, in general, to be monitored:

- (1) abnormalities in cylinder pressure, and
- (2) blow-by through suction valves or exhaust valves.

### **2.3.2 Protection Against Explosions**

1 Relief valves approved in accordance with **Table D2.4, Part D of the Rules** are to be provided for crankcases.

2 Suction manifolds and exhaust gas pipes are to be fitted with suitable pressure relief systems unless designed to withstand the worst case overpressure due to ignited gas leaks.

3 Relief valves for cylinders installed in accordance with the requirements of **2.4.2, Part D of the Rules** are to be provided, as far as practicable, with monitoring systems to verify valve closing.

4 Gas fuel injection lines are to be provided with non-return valves, and rupture disks are to be provided between gas fuel injection lines and non-return valves if necessary to prevent gas fuel injection line failure due to abnormal pressure peaks.

5 Flame arrestors are to be installed before cylinder heads in cases where gas is supplied in mixtures with air through common manifolds.

6 Engines having spaces under pistons that directly lead to crankcases are also to be in accordance with **10.3.1-2, Part GF of the Rules**.

### **2.3.3 Governors**

1 Governors for low pressure gas-fuelled engines are to be capable of being operated during gas fuel combustion mode. In the case of dual fuel engines, the governors are additionally to be capable of being operated either during gas and oil fuel (or pilot oil) combustion mode, and/or oil fuel only combustion mode.

2 The governors of -1 above are to be in accordance with the requirements in **2.4.1-1, Part D of the Rules** in each mode of operation.

3 Low pressure gas-fuelled dual fuel engines using gas fuel are to be operated in any of the following (1) to (3) modes:

- (1) controllable gas fuel supply and fixed oil fuel (pilot oil) supply,
- (2) controllable oil fuel (pilot oil) supply and fixed gas fuel supply, or
- (3) controllable gas fuel and oil fuel supplies.

## **2.4 Accessory Equipment**

### **2.4.1 Exhaust Gas Systems**

Exhaust gas pipes of low pressure gas-fuelled engines are not to be connected to the exhaust gas pipes or the exhaust pipes of other engines or systems.

### **2.4.2 Starting Systems**

Starting air branch pipes to cylinders are to be provided with effective flame arresters.

### **2.4.3 Gas Fuel Pipes**

1 Gas fuel pipes are to be provided with effective protective shielding against gas fuel bursting due to pipe failure, except where deemed appropriate by the Society

2 Spaces between the gas fuel pipes and protective shielding of low pressure gas-fuelled engines fitted in gas safe machinery spaces are to be in accordance with the requirements in **9.6, Part GF of**

**the Rules:** relevant requirements are to be applied mutatis mutandis.

**3** Only approved type flexible tubes are to be used as protective shielding.

**4** Gas fuel pipes are to be provided with systems for inerting and gas-freeing.

**5** Expansion joints provided for gas fuel pipes (only those attached to engines) are to be approved in accordance with the requirements in **Annex 1** “Guidance for Equipment and Fittings of Ships Using Low-flashpoint Fuels”.

#### **2.4.4 Cylinder Lubrication**

Cylinder lubricating systems for low pressure gas-fuelled dual fuel engines are, in general, to be capable of maintaining adequate alkali values and cylinder oil feeding rates for oil fuel only operation as well as the modes of operation specified in **2.3.3-3(1) to (3)**.

## Chapter 3      CONTROL SYSTEMS AND SAFETY SYSTEMS

### 3.1      General

1    Control systems for operating low pressure gas-fuelled engines using gas fuel are to be in accordance the requirements in **18.1 to 18.3 and 18.7, Part D of the Rules**: relevant requirements are to be applied mutatis mutandis.

2    Temperatures and pressures (or flow rates) of gas fuel supplied to low-pressure gas-fuelled engines are to be automatically controlled. In addition, visual and audible alarm devices which activate when temperatures and pressures exceed preset ranges are to be provided.

### 3.2      Low Pressure Gas-fuelled Engines of Ships Subject to the Rules for Automatic Remote Control Systems

Low pressure gas-fuelled engines of ships subject to the application of the **Rules for Automatic and Remote Control Systems** are to be in accordance with the requirements in **3.2, 3.5, 4.1 and 4.2** of said rules. In addition, such engines are to be in accordance with the following (1) and (2) requirements:

- (1) Low pressure gas-fuelled engines are to be provided with safety systems which automatically cut off the gas fuel supplies when (a), (b) or (c) given below occur. In addition, in the case of dual fuel engines, such systems are to automatically switch the mode of operation to oil fuel only or are to stop the engines. Automatic cut off of the gas fuel supplies with the double block and bleed valves specified in **9.4.4, Part GF of the Rules**, however, may be accepted.
  - (a) When the abnormalities specified in **2.3.1-1 or -2** are detected.
  - (b) When gas leaks in the double wall piping systems specified in 9.6.1, Part GF of the Rules, between inner pipes and outer pipes, or between inner pipes and ducts are detected.
  - (c) Others deemed necessary by the Society.
- (2) Low pressure engines are to be provided with systems which automatically reduce speed or switches the mode of operation to oil fuel only, and which issues alarms in the event any of the abnormalities specified in the following (a) to (d) occurs:
  - (a) abnormal gas fuel temperatures;
  - (b) abnormal gas fuel supply pressures;
  - (c) low pressures of hydraulic and pneumatic sources, or loss of electric power supply for gas fuel combustion control; or
  - (d) others deemed necessary by the Society.

## Chapter 4 TESTS

### 4.1 Prototype Tests

1 Low pressure gas-fuelled engines are to be subjected to prototype tests using gas fuel to demonstrate the design performance in accordance with prototype test plans approved by the Society. Such tests, however, may be substituted for by verification tests using one or more cylinders of a prototype engine or a similar engine in cases where deemed appropriate by the Society.

2 Parts and accessory equipment of low pressure gas-fuelled engines related to the supply and combustion of gas fuel may be required to undergo separate tests, in addition to the tests specified in -1 above, to demonstrate individual performance in cases where deemed necessary by the Society.

### 4.2 Shop Tests

#### 4.2.1 Hydraulic Tests

Pressure parts and accessory equipment with pressure parts of low pressure gas-fuelled engines are to be subjected to hydraulic tests in accordance with the requirements of **2.6.1, Part D of the Rules** and **16.7.3, Part GF of the Rules**: relevant requirements are to be applied mutatis mutandis.

#### 4.2.2 Shop Trials

1 Low pressure gas-fuelled engines are, in principle, to be subjected to shop trials using fuel gas before installed on board ship. Shop trials using only oil fuel, however, may be accepted for dual fuel engines which are identical or similar to engines which have passed the prototype tests specified in 4.1.

2 Even in cases where shop trials using only oil fuel only are approved in accordance with the requirements of -1 above, the operation of equipment related to the combustion of gas fuel is to be verified by appropriate means to be satisfactory as far as practicable.

### 4.3 Tests after Installation On Board

Control systems of low pressure gas-fuelled engines and related equipment are to be tested depending upon their installation characters in accordance with the requirements of **18.7.3, Part D of the Rules** or the requirements of **2.2.4 of the Rules for Automatic and Remote Control Systems**: relevant requirements are to be applied mutatis mutandis.

### 4.4 Sea Trials

1 Performance of control systems of low pressure gas-fuelled engines and related equipment is to be verified during operations using the gas fuel depending upon their installation characters in accordance with the requirements of **2.2.5 or 2.2.6 of the Rules for Automatic and Remote Control Systems**: relevant requirements are to be applied mutatis mutandis.

2 The sea trials specified in **2.3.1, Part B of the Rules** are to be carried out using gas fuel only. Some of the aforementioned tests, however, may be omitted in cases where deemed appropriate by the Society.



## EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2017.
2. Notwithstanding the amendments to the Guidance, the current requirements apply to ships other than ships that fall under the following:
  - (1) for which the building contract is placed on or after the effective date; 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 2017; or(Note) The term “*a similar stage of construction*” means the stage at which the construction identifiable with a specific ship begins and the assembly of that ship has commenced comprising at least 50 *tonnes* or 1%\* of the estimated mass of all structural material, whichever is the less.

\* For high speed craft, “1%” is to be read as “3%”.

  - (3) the delivery of which is on or after 1 January 2021.
3. Notwithstanding the provision of preceding 2., the amendments to the Guidance apply to the ships that fall under the following:
  - (1) which convert to using low-flashpoint fuels on or after the effective date; or
  - (2) which, on or after the effective date, undertake to use low-flashpoint fuels different from those which it was originally approved to use before the effective date.