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ClassNK

Guidelines for Ships Using Alternative Fuels (Edition 1.1)
(Methyl / Ethyl Alcohol / LPG / Ammonia)

[English]

Introduction

Amendments to MARPOL Annex VI entered into force effective from 1 July 2010 concerning increasingly stringent requirements for nitrogen oxide (NOx) emissions from ships. Under these requirements, marine diesel engines have been subject to mandatory NOx Tier II requirements from 1 January 2011 that are about 15% to 22% lower than the NOx emission limits previously set under Tier I. Marine diesel engines also have been subject to NOx Tier III requirements from January 2016 in Emission Control Areas (ECA) in which engines are required to satisfy a stricter limit that is about 80% lower than the Tier I NOx emission limits. In addition, ships on the open sea are now subject to a maximum limit on sulphur content of 3.5% *m/m* for fuel used from 1 January 2012 for sulfur oxide (SOx) emission reduction, and this maximum limit on sulfur content will be further reduced to 0.5% *m/m* from 1 January 2020. Moreover, ships have been subject to a maximum limit on sulphur content of 0.1% *m/m* from January 2015 when operating in ECAs. Further amendments to MARPOL Annex VI adopted at IMO MEPC 62 in July 2011 also set forth new restrictions on carbon dioxide (CO_2) emissions from ships that have been effective from 1 January 2013, and the GHG reduction strategy adopted by the IMO at MEPC 72 in April 2018 is expected to lead to a 40% or more improvement in fuel efficiency (CO_2 emissions per transport volume) by 2030 as well as a 50% reduction in total GHG emissions by 2050 for the international shipping industry as a whole in comparison to 2008 values. These expected reductions will be a big step towards the early realization of the goal of zero GHG emissions from international shipping during this century established by the IMO.

In light of the above in mind and as the establishment of regulations for preventing air pollution and global warming continues to progress, the use of earth-friendly alternative fuels instead of petroleum fuels is being actively studied for their potential to be the next-generation of marine fuels. Since the LNG, LPG and methanol/ethanol based fuels currently being developed as alternatives to more traditional fuel oil do not contain any sulphur, their use can lead to significant reductions in SOx emissions. In addition, the premixed lean-burn engine type currently used by many LNG fueled ships can reduce NOx emissions by 90% or more, and equipping a ship with such engines alone (i.e. no additional means are needed) is seen as being sufficient to comply with Tier III regulations. Finally in regard to CO_2 emissions, it is theoretically possible to reduce CO_2 emissions by 10% to 20% when using LNG, LPG or methanol/ethanol based fuels, and the use of decarbonized fuels such as ammonia and hydrogen is seen as a major step towards helping to achieve the goal of zero GHG emissions.

Since alternative fuels based on LNG, LPG and methanol/ethanol have lower flashpoints than conventional fuel oils, their usage comes with the increased risk of fire or developing an explosive atmosphere if they are leaked into the ship; therefore, it is necessary to put in to place well-considered safety measures to mitigate such risks as much as possible. For this reason, the IMO discussed the development of internationally common safety requirements for ships using gas or other low-flashpoint fuels, and these discussions led to the adoption of the *International Code of Safety for Ships*

Using Gases of Other Low-flashpoint Fuels (more commonly referred to as the “IGF Code”) at the 95th Session of the IMO Maritime Safety Commission (MSC 95) held in June 2015. The IGF Code is a compulsory code for SOLAS, and it has been in effect since January 1, 2017. ClassNK (hereinafter referred to as “the Society”), in turn, added a new part to its Rules and Guidance for the Survey and Construction of Steel Ships in 2017 called *Part GF: Ships Using Low Flashpoint Fuels* in order to fully incorporate the requirements of the IGF Code into its technical rules. The Society also released its own independently developed *Guidelines for Ships Using Low-Flashpoint Fuels (Methyl/Ethyl Alcohol / LPG* (hereinafter referred to as “the Guidelines) in 2019. The Guidelines includes the Society’s own independently developed requirements related to the latest technologies regarding the safety requirements for ships that use methanol/ethanol or LPG as fuel, which are matters not stipulated in the regulations of the current IGF Code.

In addition to the above, the Society has also been keeping abreast of trends in alternative fuel development and has been paying particularly close attention to the increased interest that ammonia has been attracting in recent years due to its potential for use as a decarbonized fuel; ammonia, however, is said to be difficult to burn which means that it is necessary to give careful consideration to how its usage may impact human health and ship structural integrity respectively due to its toxicity and corrosivity. With this in mind, the Society decided to update the Guidelines to reflect this recent trend by adding requirements related to the safe use of ammonia as an alternative fuel with respect to both ships and their personnel, and to also change the name of the Guidelines to the “Guidelines for Ships Using Alternative Fuels [Edition 1.0]”. Furthermore, although Annex 1 “LNG Ready Ship” of the old Guidelines states that the notation “LNG Ready” can be affixed to classification characters of ships that do not use gas-based fuels at the time of their construction but are designed and partially equipped for the future use of such fuels, the annex was reviewed to make sure that it can be applied to alternative fuels other than LNG such as LPG, methanol/ethanol, ammonia, etc. as well, and the name of the annex was correspondingly changed to “Alternative Fuel Ready Ship”.

We hope the Guidelines will provide practical guidance for shipyards, manufacturers, shipowners, managers, and operators looking to prepare their fleets for a safer and greener future. Its purpose is to simply provide support to designers with respect to the current requirements, and it will be amended as may be deemed necessary in accordance with any changes made to the IGF Code by the IMO as well as in consideration of any new technologies introduced in the future.

Part A

Guidelines for ships using Methyl/Ethyl Alcohol as Fuels

CONTENTS

Chapter 1 PREAMBLE 1
Chapter 2 GENERAL 2
2.1 Application 2
2.2 Definitions 2
2.3 Alternative design 2
Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS 3
3.1 Goal 3
3.2 Functional requirements 3
Chapter 4 GENERAL REQUIREMENTS 4
4.1 Goal 4
4.2 Risk assessment 4
4.3 Limitation of explosion consequences 4
Chapter 5 SHIP DESIGN AND ARRANGEMENT 5
5.1 Goal 5
5.2 Functional requirements 5
5.3 General requirements 5
5.4 Independent fuel tanks 5
5.5 Portable tanks 6
5.6 Machinery space 6
5.7 Location and protection of fuel piping 7
5.8 Fuel preparation spaces design 8
5.9 Bilge systems 8
5.10 Drip trays 8
5.11 Arrangement of entrances and other openings in enclosed spaces 8
5.12 Airlocks 9
Chapter 6 FUEL CONTAINMENT SYSTEM 10
6.1 Goal 10
6.2 Functional requirements 10
6.3 Fuel tanks venting and gas freeing system 10
6.4 Inerting and atmospheric control within the fuel storage system 11
6.5 Inert gas availability on board 12
Chapter 7 MATERIAL AND GENERAL PIPE DESIGN 14
7.1 Goal 14
7.2 Functional requirements 14
7.3 General pipe design 14
7.4 Piping fabrication and joining details 15
7.5 Materials 16
Chapter 8 BUNKERING 17
8.1 Goal 17
8.2 Functional requirements 17
8.3 Bunkering station 17
8.3.1 General requirements 17

8.3.2 Ships bunker hoses 17
8.4 Manifold 18
8.5 Bunkering system 18
Chapter 9 FUEL SUPPLY TO CONSUMERS..19
9.1 Goal..19
9.2 Functional requirements 19
9.3 General requirements 19
9.4 Fuel distribution..19
9.5 Redundancy of fuel supply 19
9.6 Safety functions of the fuel supply system..20
9.7 Fuel preparation spaces and pumps..20
Chapter 10 POWER GENERATION INCLUDING PROPULSION AND OTHER ENERGY CONVERTERS21
10.1 Goal 21
10.2 Functional requirements..21
10.3 General requirements..21
10.4 Dual-fuel engines..21
10.5 Single fuel engines..22
Chapter 11 FIRE SAFETY..23
11.1 Goal 23
11.2 Functional requirements..23
11.3 General requirements..23
11.4 Fire protection 23
11.5 Fire main..23
11.6 Firefighting 23
11.7 Extinguishing of engine-room and fuel preparation space 24
Chapter 12 EXPLOSION PREVENTION AND AREA CLASSIFICATION..25
12.1 Goal 25
12.2 Functional requirements..25
12.3 General requirements..25
12.4 Area classification 25
12.5 Hazardous area zones..25
12.5.1 Hazardous area zone 0:..26
12.5.2 Hazardous area zone 1 26
12.5.3 Hazardous area zone 2 26
Chapter 13 VENTILATION..27
13.1 Goal 27
13.2 Functional requirements..27
13.3 General..27
13.4 Fuel preparation spaces..28
13.5 Bunkering station..29
13.6 Ducts and double wall pipes 29
Chapter 14 ELECTRICAL INSTALLATIONS..30
14.1 Goal 30
14.2 Functional requirements..30
14.3 General..30

Chapter 15 CONTROL, MONITORING AND SAFETY SYSTEMS 31
15.1 Goal 31
15.2 Functional requirements 31
15.3 General requirements 31
15.4 Bunkering and fuel tank pipe monitoring 32
15.4.1 Level indicators for fuel tanks 32
15.4.2 Overflow control 32
15.5 Bunkering control 32
15.6 Engine monitoring 32
15.7 Gas detection 33
15.8 Fire detection 33
15.9 Ventilation 33
15.10 Safety functions of fuel supply systems 34
Chapter 16 DRILLS AND EMERGENCY EXERCISES 37
16.1 Goal 37
Chapter 17 OPERATION 38
17.1 Goal 38
17.2 Functional requirements 38
17.3 Requirements for maintenance 38
17.4 Requirements for bunkering operations 38
17.4.1 Responsibilities 38
17.4.2 Overview of control, automation and safety systems 39
17.4.3 Pre-bunkering verification 39
17.4.4 Ship bunkering source communications 39
17.4.5 Electrical bonding 40

Chapter 1 PREAMBLE

These guidelines provide provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using methyl/ethyl alcohol as fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved..

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

Chapter 2 to **17** of these guidelines are based on IGF Code. **Chapter 2** to **4** provide functional requirements and general requirements for ships using low-flashpoint fuel (except for liquefied gas carriers) and **Chapter 5** to **17** separately provide special requirements as **Part A** which apply to ships using methyl/ethyl alcohol as fuel and as **Part B** which apply to ships using LPG as fuel. On the other hand, **Part C** of these guidelines provide the safety requirements based on Chapter 16 of IGC Code which apply to liquefied gas carriers using LPG as fuel in addition to the relevant requirements of IGC Code.

Chapter 2 GENERAL

2.1 Application

1 **Chapter 2** to **17** of these Guidelines apply to ships using methyl/ethyl alcohol as fuel (except for liquefied gas carriers).

2 The requirements in these Guidelines are specified on the premise of application to the ships to which SOLAS Convention applies. However, if it is difficult to comply with the requirements of these Guidelines due to the size of the ships, etc., special considerations may be given to the conditions provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

2.2 Definitions

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2 and **2.2, Part GF of the Rules for the Survey and Construction of Steel Ships.**

1 *Ethyl alcohol* means C_2H_5OH, either in liquid or vapour state.

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

3 *Methyl alcohol* means CH_3OH, either in liquid or vapour state.

4 *Single failure* is where loss of intended function occurs through one fault or action.

5 *Fuel* means methyl/ethyl alcohol fuels, containing allowable additives or impurities, suitable for the safe operation on board ships, complying with an international standard.

2.3 Alternative design

1 These Guidelines contains functional requirements for all appliances and arrangements related to the usage of methyl/ethyl alcohol fuels.

2 Appliances and arrangements of methyl/ethyl alcohol fuel systems may deviate from those set out in these Guidelines, provided such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

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

Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of these Guidelines 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 methyl/ethyl alcohol as fuel.

3.2 Functional requirements

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

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

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

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

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

6 Unintended accumulation of explosive, flammable or toxic vapour and liquid concentrations should be prevented.

7 System components should be protected against external damage.

8 Sources of ignition in hazardous areas should be minimized to reduce the probability of fire and explosions.

9 Safe and suitable fuel supply, storage and bunkering arrangements should be provided, capable of receiving and containing the fuel in the required state without leakage.

10 Piping systems, containment and overpressure relief arrangements that are of suitable design, material, construction and installation for their intended application should be provided.

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

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

13 Fixed fuel vapour and/or leakage detection suitable for all spaces and areas concerned should be arranged.

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

15 Commissioning, trials and maintenance of fuel systems and fuel utilization machinery should satisfy the goal in terms of safety, availability and reliability.

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

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

Chapter 4 GENERAL REQUIREMENTS

4.1 Goal

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

4.2 Risk assessment

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

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

4.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release1 and potential ignition sources should not:

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

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

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

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

5 damage life-saving equipment or associated launching arrangements;

6 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;

7 affect other areas of the vessel 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 (LSA) or impede escape routes.

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

Chapter 5 SHIP DESIGN AND ARRANGEMENT

5.1 Goal

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

5.2 Functional requirements

This chapter is related to functional requirements **3.2.1**, **3.2.2**, **3.2.3**, **3.2.5**, **3.2.6**, **3.2.7**, **3.2.12**, **3.2.14** and **3.2.16**. In particular, the following apply:

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

2 Fuel containment systems, fuel piping and other fuel release sources should be so located and arranged that released fuel, either as vapour or liquid is led to safe locations.

3 The access or other openings to spaces containing potential sources of fuel release should be so arranged that flammable, asphyxiating or toxic vapours or liquids cannot escape to spaces that are not designed for the presence of such substances.

4 Fuel piping should be protected against mechanical damage.

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

6 The probability of a fire or explosion in a machinery space as a result of a fuel release should be minimized in the design, with special attention on the risk of leakage from pumps, valves and connections.

5.3 General requirements

1 Tanks containing fuel should not be located within the accommodation spaces or machinery spaces of category A.

2 Integral fuel tanks should be surrounded by protective cofferdams, except on those surfaces bound by shell plating below the lowest possible waterline, other fuel tanks containing methyl/ethyl alcohol, or fuel preparation space.

3 The fuel containment system should be abaft of the collision bulkhead and forward of the aft peak bulkhead.

4 Fuel tanks located on open decks should be protected against mechanical damage.

5 Fuel tanks on open decks should be surrounded by coamings and spills should be collected in a dedicated holding tank.

6 Special consideration should be given to chemical tankers using methyl/ethyl alcohol cargoes as fuel.

5.4 Independent fuel tanks

1 Independent tanks may be accepted on open decks or in a fuel storage hold space.

2 Independent tanks should be fitted with:

(1) mechanical protection of the tanks depending on location and cargo operations;

(2) if located on an open deck: drip tray arrangements for leak containment and water spray systems for emergency cooling; and

(3) if located in a fuel storage hold space: the space should meet the requirements of **chapter 11** and **13**.

3 Independent fuel tanks should be secured to the ship's structure. The arrangement for supporting and fixing the tanks should be designed for the maximum expected static, dynamic inclinations and accidental loads as well as the maximum expected values of acceleration, taking into account the ship characteristics and the position of the tanks.

5.5 Portable tanks

1 Portable fuel tanks should be located in dedicated areas fitted with:

(1) mechanical protection of the tanks depending on location and cargo operations;

(2) if located on an open deck: drip tray arrangements for leak containment and water spray systems for emergency cooling; and

(3) if located in a fuel storage hold space, the space should meet the requirements of **chapter 11** and **13**.

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

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

4 Connections to the ship's fuel piping systems should be made by means of approved flexible hoses suitable for methyl/ethyl alcohol or other suitable means designed to provide sufficient flexibility.

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

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

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

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

9 When connected to the ship's fuel piping system,

(1) each portable tank should be capable of being isolated at any time;

(2) isolation of one tank should not impair the availability of the remaining portable tanks; and

(3) the tank should not exceed its filling limits.

5.6 Machinery space

1 A single failure within the fuel system should not lead to a release of fuel into the machinery space.

2 All fuel piping within machinery space boundaries should be enclosed in gas and liquid tight enclosures in accordance with 9.4.

5.7 Location and protection of fuel piping

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

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

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

4 Fuel piping should comply with the following:

(1) Fuel piping that passes through enclosed spaces in the ship should be enclosed in a pipe or duct that is gas and liquid tight towards the surrounding spaces with the fuel contained in the inner pipe. Such double walled piping is not required in cofferdams surrounding fuel tanks, fuel preparation spaces, spaces containing independent fuel tanks as the boundaries for these spaces will serve as a second barrier.

(2) All fuel pipe should be self-draining to suitable fuel or collecting tanks in normal condition of trim and list of the ship. Alternative arrangements for draining the piping may be accepted by the Society;

5.8 Fuel preparation spaces design

Fuel preparation spaces, should be located outside machinery spaces of category A.

5.9 Bilge systems

1 Bilge systems installed in areas where methyl/ethyl alcohol can be present should be segregated from the bilge system of spaces where methyl alcohol or ethyl alcohol cannot be present.

2 One or more holding tanks for collecting drainage and any possible leakage of methyl/ethyl alcohol from fuel pumps, valves or from double walled inner pipes, located in enclosed spaces should be provided. Means should be provided for safely transferring contaminated liquids to onshore reception facilities.

3 The bilge system serving the fuel preparation space should be operable from outside the fuel preparation space.

5.10 Drip trays

1 Drip trays should be fitted where leakage and spill may occur, in particular in way of single wall pipe connections.

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

3 Each drip tray should be provided with means to safely drain spills or transfer spills to a dedicated holding tank. Means for preventing backflow from the tank should be provided.

4 Drip trays for leakage of less than 10 litres maybe provided with means for manual emptying.

5 The holding tank should be equipped with a level indicator and alarm and should be inerted at all times during normal operation.

5.11 Arrangement of entrances and other openings in enclosed spaces

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

2 Fuel preparation spaces should have independent access direct from open deck, where practicable. Where a separate access from open deck is not practicable, an airlock complying with chapter **5.12** should be provided.

3 Fuel tanks and surrounding cofferdams should have suitable access from the open deck, where practicable, for gas-freeing, cleaning, maintenance and inspection.

4 Without direct access to open deck, an entry space to fuel tanks or surrounding cofferdams, should be provided and comply with the following:

(1) be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm and a gas detection alarm should be fitted;

(2) have sufficient open area around the fuel tank hatch for efficient evacuation and rescue operation;

(3) not be an accommodation space, service space, control station or machinery space of category A; and

(4) a cargo space may be accepted as an entry space, depending upon the type of cargo, if the area is cleared of cargo and no cargo operation is undertaken during entry to the space.

5 The area around independent fuel tanks should be sufficient to carry out evacuation and rescue operations.

6 For safe access, horizontal hatches or openings to or within fuel tanks or surrounding cofferdams should have a minimum clear opening of 600 x 600 mm that also facilitates the hoisting of an injured person from the bottom of the tank/cofferdam. For access through vertical openings providing main passage through the length and breadth within fuel tanks and cofferdams, the minimum clear opening should not be less than 600 X 800 mm at a height of not more than 600 mm from bottom plating unless gratings or footholds are provided. Smaller openings may be accepted provided evacuation of an injured person from the bottom of the tank/cofferdam can be demonstrated.

5.12 Airlocks

1 An airlock is a space enclosed by gas tight bulkheads with two gas tight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of **Chapter 18, 19** and **20**, **Part C of the Rules for the Survey and Construction of Steel Ships**, the door sill should not be less than 300 mm in height. The doors should be self-closing without any hold-back arrangements.

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

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

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

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

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

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

Chapter 6 FUEL CONTAINMENT SYSTEM

6.1 Goal

The goal of this chapter is to provide for a fuel containment system where the risk to the ship, its crew and to the environment is minimized to a level that is at least equivalent to a conventional oil fuelled ship.

6.2 Functional requirements

This chapter refers to functional requirements in **3.2.1**, **3.2.2**, **3.2.5** and **3.2.8** to **3.2.16**.

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

(1) flammable fuels spreading to locations with ignition sources;

(2) toxicity potential and risk of oxygen deficiency or other negative impacts on crew health due to fuels and inert gases;

(3) restriction of access to muster stations, escape routes and/or LSAs; and

(4) reduction in availability of LSAs.

2 The fuel containment system and the fuel supply system should be so designed that safety actions after any leakage, irrespective of in liquid or vapour phase, do not lead to an unacceptable loss of power.

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

6.3 Fuel tanks venting and gas freeing system

1 The fuel tanks should be fitted with a controlled tank venting system.

2 A fixed piping system should be arranged to enable each fuel tank to be safely gas freed, and to be safely filled with fuel from a gas-free condition.

3 The formation of gas pockets during gas freeing operation should be avoided by considering the arrangement of internal tank structure and location of gas freeing inlets and outlets.

4 Pressure and vacuum relief valves should be fitted to each fuel tank to limit the pressure or vacuum in the fuel tank. The tank venting system may consist of individual vents from each fuel tank or the vents from each individual fuel tank may be connected to a common header. Design and arrangement should prevent flame propagation into the fuel containment system. If pressure relief valves (PRVs) of the high velocity type are fitted to the end of the vent pipes, they should be certified for endurance burning in accordance with **MSC/Circ.677**. If PRVs are fitted in the vent line, the vent outlet should be fitted with a flame arrestor certified for endurance burning in accordance with **MSC/Circ.677**.

5 Shut off valves should not be arranged either upstream or downstream of the PRVs. By-pass valves may be provided. For temporary tank segregation purposes (maintenance) shut-off valves in common vent lines may be accepted if a secondary independent over/under pressure protection is provided to all tanks as per **6.3.7**.

6 The fuel tank controlled venting system should be designed with redundancy for the relief of full flow overpressure and/or vacuum. Pressure sensors fitted in each fuel tank, and connected to an alarm system, may be accepted in lieu of the secondary redundancy requirement for pressure relief. The opening pressure of the PRVs should not be lower than 0.007 MPa below atmospheric pressure.

7 PRVs should vent to a safe location on open deck and should be of a type which allows the functioning of the valve to be easily checked.

8 The fuel tank vent system should be sized to permit bunkering at a design loading rate without over pressurizing the fuel tank.

9 The fuel tank vent system should be connected to the highest point of each tank and vent lines should be self-draining under all normal operating conditions.

6.4 Inerting and atmospheric control within the fuel storage system

1 All fuel tanks should be inerted at all times during normal operation.

2 Cofferdams should be arranged either for purging or filling with water through a non- permanent connection. Emptying the cofferdams should be done by a separate drainage system, e.g. bilge ejector.

3 The system should be designed to eliminate the possibility of a flammable mixture atmosphere existing in the fuel tank during any part of the atmosphere change operation, gas freeing or inerting by utilizing an inerting medium.

4 To prevent the return of flammable liquid and vapour to the inert gas system, the inert gas supply line should 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 should be installed between the double block and bleed arrangement and the fuel system. These valves should be located inside hazardous spaces.

5 Where the connections to the inert gas piping systems are non-permanent, two non-return valves may substitute the valves required in 6.4.4.

6 Blanking arrangements should be fitted in the inert gas supply line to individual tanks. The position of the blanking arrangements should be immediately obvious to personnel entering the tank. Blanking should be via removable spool piece.

7 Fuel tank vent outlets should be situated normally not less than 3 m above the deck or gangway if located within 4 m from such gangways. The vent outlets are also to be arranged at a distance of at least 10 m from the nearest air intake or opening to accommodation and service spaces and ignition sources. The vapour discharge should be directed upwards in the form of unimpeded jets.

8 Vapour outlets from fuel tanks should be provided with devices tested and type approved to prevent the passage of flame into the tank. Due attention should be paid in the design and position of the PRVs with respect to blocking and due to ice during adverse weather conditions. Provision for inspection and cleaning should be arranged.

9 The arrangements for gas-freeing and ventilation of fuel tanks should be such as to minimize the hazards due to the dispersal of flammable vapours to the atmosphere and to flammable gas mixture in the tanks. The ventilation system for fuel tanks should be exclusively for ventilating and gas freeing purposes. Connection between fuel tank and fuel preparation space ventilation will not be accepted.

10 Gas-freeing operations should be carried out such that vapour is initially discharged in one of the following ways:

(1) through outlets at least 3 m above the deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas freeing operation;

(2) through outlets at least 3 m above the deck level with a vertical efflux velocity of at least 20 m/s which are protected by suitable devices to prevent the passage of flame; or

(3) through outlets underwater

11 In designing a gas-freeing system in conformity with **6.3.2** due consideration should be given to the following:

(1) materials of construction of system;

(2) time to gas-free;

(3) flow characteristics of fans to be used;

(4) the pressure losses created by ducting, piping, fuel tank inlets and outlets;

(5) the pressure achievable in the fan driving medium (e.g. water or compressed air); and

(6) the densities of the fuel vapour/air mixture.

6.5 Inert gas availability on board

1 Inert gas should be available permanently on board in order to achieve at least one trip from port to port considering maximum consumption of fuel expected and maximum length of trip expected and to keep tanks inerted during two weeks in harbour with minimum port consumption.

2 A production plant and/or adequate storage capacities might be used to achieve availability target defined in **6.5.1.**

3 Fluid used for inerting should not modify the characteristics of the fuel.

4 The production plant, if fitted, should be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5% oxygen content by volume. The system should be designed to ensure that if the oxygen content exceeds 5% by volume, the inert gas should be automatically vented to atmosphere.

5 The system should be able to maintain an atmosphere with an oxygen content not exceeding 8% by volume in any part of any fuel tank

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

7 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment should be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. If the oxygen content is below 19% in the separate compartment an alarm should be given. A minimum of two oxygen sensors to be provided in each space. Visual and audible alarm should be placed at each entrance to the inert gas room.

8 Nitrogen pipes should only be led through well ventilated spaces. Nitrogen pipes in enclosed spaces should:

(1) have only a minimum of flange connections as needed for fitting of valves and be fully welded otherwise; and

(2) be as short as possible.

9 Notwithstanding the provisions of section 6.5, inert gas utilized for gas freeing of tanks may be provided externally to the ship.

Chapter 7 MATERIAL AND GENERAL PIPE DESIGN

7.1 Goal

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

7.2 Functional requirements

This chapter relates to functional requirements **3.2.1**, **3.2.5**, **3.2.6**, **3.2.8**, **3.2.9** and **3.2.10**, of these Guidelines. In particular, all materials used should be suitable for the fuel under the maximum working pressure and temperature.

7.3 General pipe design

1 The design pressure for any section of the fuel piping system is the maximum gauge pressure to which the system may be subjected in service, taking into account the highest set pressure on any relief valve on the system..

2 The wall thickness of pipes made of steel should not be less than:

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

t_0 = theoretical thickness, mm

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

P = system design pressure, but not less than the design pressure given in 7.3.1, MPa

D = outside pipe diameter

K = allowable stress N/mm^2. See 7.3.3

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

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

$$b = \frac{Dt_0}{2.5r}$$ where: r = mean radius of the bend (mm)

c = corrosion allowance (mm). If corrosion or erosion is expected, the wall thickness of piping should be increased over that required by the other design requirements.

a = negative manufacturing tolerance for thickness (%)

3 For pipes made of steel the allowable stress K to be considered in the formula for t_0 in **7.3.2** is the lower of the following values

Rm / *A* or *Re* / *B*

Where:

Rm = specified minimum tensile strength at ambient temperature (N/mm^2)

Re = specified minimum yield stress at ambient temperature (N/mm^2). If stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

The values of *A* and *B* should be at least A=2.7 and B=1.8.

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

5 For pipes made of materials other than steel, the allowable stress should be considered by the Society.

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

(1) stresses due to the weight of the piping system;

(2) acceleration loads when significant; and

(3) internal pressure and loads induced by hog and sag of the ship.

Note: Whether a fuel system should be considered as a high pressure system for the purpose of these guidelines depends on the design and arrangement of the specific system. Accordingly the stress analysis should be waived or done to the satisfaction of the Society.

7 Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance should be colour marked in accordance with a standard at least equivalent to those acceptable to the Society.

8 All fuel piping and independent fuel tanks should be electrically bonded to the ship's hull. Electrical conductivity should be maintained across all joints and fittings. Electrical resistance between piping and the hull should be maximum 10^6 Ohm..

9 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 should only contain piping or cabling necessary for operational purposes.

10 Filling lines to fuel tanks should be arranged to minimize the possibility for static electricity, e.g. by reducing the free fall into the fuel tank to a minimum

11 The arrangement and installation of fuel piping should provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account. Expansion bellows should not be used.

7.4 Piping fabrication and joining details

1 The inner piping, where a protective duct is required, is to be full penetration butt welded, and fully radiographed. Flange connections in this piping are to only be permitted within the tank connection space and fuel preparation space or similar;

(1) During the use of the fuel piping, all doors, ports and other openings on the corresponding superstructure or deckhouse side should normally be kept closed;

(2) The annular space in the double walled fuel piping should be segregated at the engine room bulkhead. This implies that there should be no common ducting between the engine room and other spaces.

2 Piping for fuel should be joined by welding except

(1) for approved connections to shut-off valve and expansion joints, if fitted; and

(2) for other exceptional cases specifically approved by the Society.

3 The following direct connections of pipe length without flanges may be considered:

(1) Butt-welded joints with complete penetrations at the root;

(2) Slip-on welded joints with sleeves and related welding having dimensions in accordance with recognized standards should only be used in pipes having an external diameter of 50 mm or less. The possibility for corrosion to be considered; and

(3) Screwed connections, in accordance with recognized standards, should only be used for piping with an external diameter of 25 mm or less.

4 Welding, post-weld heat treatment, radiographic testing, dye penetrating testing, pressure testing, leakage testing and non-destructive testing should be performed in accordance with recognized standards. Butt welding should be subject to 100% non-destructive testing, while sleeve welds should be subject to at least 10% liquid penetrant testing (PT) or magnetic particle testing (MT).

5 Where flanges are used they should be of the welded neck or slip-on type. Socket welds are not to be used in nominal sizes above 50 mm.

6 Expansion of piping should normally be allowed for by the provision of expansion loops or bends in the fuel piping system. Use of expansion joints used in high pressure fuel systems should be approved by the Society. Slip joints should not be used.

Note: Whether a fuel system should be considered as a high pressure system for the purpose of these guidelines depends on the design and arrangement of the specific system.

7 Other connections: Piping connections should be joined in accordance with **7.4.2** but for other exceptional cases the Society may consider alternative arrangements.

7.5 Materials

Due consideration should be taken with respect to the corrosive nature of fuel when selecting materials.

Chapter 8 BUNKERING

8.1 Goal

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

8.2 Functional requirements

This chapter relates to functional requirements **3.2.1**, **3.2.2**, **3.2.3**, **3.2.4**, **3.2.5**, **3.2.6**, **3.2.7**, **3.2.8**, **3.2.9**, **3.2.10**, **3.2.11**, **3.2.13**, **3.2.14**, **3.2.15** and **3.2.16** of these Guidelines. In particular, the piping system for transfer of fuel to the fuel tank should be designed such that any leakage from the piping system cannot cause danger to the persons onboard, the environment or the ship.

8.3 Bunkering station

8.3.1 General requirements

1 The bunkering station should be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration with respect to provisions for mechanical ventilation. The Society may require special risk assessment.

2 Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations should not face the bunkering station.

3 Closed or semi-enclosed bunkering stations should be surrounded by gas and liquid tight boundaries against enclosed spaces.

4 Bunkering lines should not be led directly through accommodation, control stations or service spaces. Bunkering lines passing through non-hazardous areas in enclosed spaces should be double walled or located in gas-tight ducts.

5 Arrangements should be made for safe management of fuel spills. Coamings and/or drip trays should be provided below the bunkering connections together with a means of safely collecting and storing spills. This could be a drain to a dedicated holding tank equipped with a level indicator and alarm. Where coamings or drip trays will be subject to rain water, provisions should be made to drain rain water overboard.

6 Showers and eye wash stations for emergency usage are to be located in close proximity to areas where the possibility for accidental contact with fuel exists. The emergency showers and eye wash stations to be operable under all ambient conditions.

8.3.2 Ships bunker hoses

1 Bunker hoses carried on board are to be suitable for methyl/ethyl alcohol. Each type of bunker hose, complete with end-fittings, should be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test should demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature. Hoses used for prototype testing should not be used for bunker service.

2 Before being placed in service, each new length of bunker hose produced should be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure, but not more than two fifths of its bursting pressure. The hose should be stencilled, or otherwise marked, with the date of testing, its specified maximum working pressure and, if used in services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure should not be less than 1 MPa gauge.

3 Means should be provided for draining any fuel from the bunkering hoses upon completion of operation.

4 Where fuel hoses are carried on board, arrangements should be made for safe storage of the hoses. Hoses should be stored on the open deck or in a storage room with independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour.

8.4 Manifold

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

8.5 Bunkering system

1 Means should be provided for draining any fuel from the bunkering lines upon completion of operation.

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

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

4 In the bunkering line, as close to the connection point as possible, there should be a manually operated stop valve and a remotely operated shutdown valve arranged in series. Alternatively, a combined manually operated and remote shutdown valve may be provided. It should be possible to operate this remotely operated valve from the bunkering control station.

5 Where bunkering lines are arranged with a cross-over suitable isolation arrangements should be provided to ensure that fuel cannot be transferred inadvertently to the ship side not in use for bunkering.

Chapter 9 FUEL SUPPLY TO CONSUMERS

9.1 Goal

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

9.2 Functional requirements

This chapter is related to functional requirements **3.2.1**, **3.2.2**, **3.2.3**, **3.2.4**, **3.2.5**, **3.2.6**, **3.2.8**, **3.2.9**, **3.2.10**, **3.2.11**, **3.2.13**, **3.2.14**, **3.2.15** and **3.2.16** of these Guidelines.

9.3 General requirements

1 The fuel piping system should be separate from all other piping systems.

2 The fuel supply system should be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection. The causes and consequences of release of fuel should be subject to special consideration within the risk assessment in **4.2**.

3 The piping system for fuel transfer to the consumers should 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.

4 Fuel lines should be installed and protected so as to minimize the risk of injury to persons on board in case of leakage.

9.4 Fuel distribution

1 The outer pipe or duct should be gas and liquid tight.

2 The annular space between inner and outer pipe should have mechanical ventilation of underpressure type with a capacity of minimum 30 air changes per hour and be ventilated to open air. Appropriate means for detecting leakage into the annular space should be provided. The double wall enclosure should be connected to a suitable draining tank allowing the collection and the detection of any possible leakage.

3 Inerting of the annular space might be accepted as an alternative to ventilation. Appropriate means of detecting leakage into the annular space should be provided. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes.

4 The outer pipe in the double walled fuel pipes should be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes. As an alternative the calculated maximum built up pressure in the duct in the case of an inner pipe rupture may be used for dimensioning of the duct.

9.5 Redundancy of fuel supply

Propulsion and power generation arrangements, together with fuel supply systems should be arranged, so that a failure in fuel supply does not lead to an unacceptable loss of power.

9.6 Safety functions of the fuel supply system

1 All fuel piping should be arranged for gas-freeing and inerting.

2 Fuel tank inlet and outlet valves should be as close to the tank as possible. Valves required to be operated under normal operation such as when fuel is supplied to consumers or during bunkering should be remotely operated if not easily accessible.

3 The main fuel supply line to each consumer or set of consumers should be equipped with an automatically-operated master fuel valve. The master fuel valve(s) should be situated in the part of the piping that is outside the machinery space containing methyl/ethyl alcohol fuelled consumer(s). The master fuel valve(s) should automatically shut off the fuel supply in accordance with **15.2.1.2** and **table 1** in **chapter 15**.

4 Means of manual emergency shutdown of fuel supply to the consumers or set of consumers should be provided on the primary and secondary escape routes from the consumer compartment, at a location outside consumer space, outside the fuel preparation space and at the bridge. The activation device should be arranged as a physical button, duly marked and protected against inadvertent operation and operable under emergency lighting.

5 The fuel supply line to each consumer should be provided with a remote operated shut-off valve.

6 There should be one manually operated shutdown valve in the fuel line to each consumer to ensure safe isolation during maintenance.

7 Valves should be of the fail-safe type.

8 When pipes penetrate the fuel tank below the top of the tank a remotely operated shut-off valve should be fitted to the fuel tank bulkhead. When the fuel tank is adjacent to a fuel preparation space, the valve may be fitted on the tank bulkhead on the fuel preparation space side.

9.7 Fuel preparation spaces and pumps

1 Any fuel preparation space should not be located within a machinery space of category A, should be gas and liquid tight to surrounding enclosed spaces and vented to open air.

2 Hydraulically powered pumps that are submerged in fuel tanks should be arranged with double barriers preventing the hydraulic system serving the pumps from being directly exposed to methyl/ethyl alcohol. The double barrier should be arranged for detection and drainage of eventual methyl/ethyl alcohol leakage.

3 All pumps in the fuel system should be protected against running dry (i.e. protected against operation in the absence of fuel or service fluid). All pumps which are capable of developing a pressure exceeding the design pressure of the system should be provided with relief valves. Each relief valve should be in closed circuit, i.e. arranged to discharge back to the piping upstream of the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

Chapter 10 POWER GENERATION INCLUDING PROPULSION AND OTHER ENERGY CONVERTERS

10.1 Goal

To provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

1 This chapter is related to functional requirements as described in **3.2.1**, **3.2.11**, **3.2.13**, **3.2.14**, **3.2.15**, **3.2.16** and **3.2.17**. In particular the following apply:

(1) The exhaust system should be designed to prevent any accumulation of unburnt fuel.

(2) Each fuel consumer should have a separate exhaust system.

2 One single failure in the fuel system should not lead to an unacceptable loss of power.

10.3 General requirements

1 All engine components and engine related systems should be designed in such a way that fire and explosion risks are minimized.

2 Engine components containing methyl/ethyl alcohol fuel should be effectively sealed to prevent leakage of fuel into the machinery space.

3 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase should be carried out and reflected in the safety concept of the engine.

4 A means should be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, continued operation may be allowed provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.

10.4 Dual-fuel engines

1 In case of shut-off of the methyl/ethyl alcohol supply, the engines should be capable of continuous operation by oil fuel only without interruption.

2 An automatic system should be fitted to change over from methyl/ethyl alcohol fuel operation to oil fuel operation with minimum fluctuation of the engine power. Acceptable reliability should be demonstrated through testing. In the case of unstable operation on engines when methyl/ethyl alcohol firing, the engine should automatically change to oil fuel mode. There should also be possibility for manual change over.

3 In case of an emergency stop or a normal stop the methyl/ethyl alcohol fuel should be automatically shut off not later than the pilot oil fuel. It should not be possible to shut off the pilot oil fuel without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

10.5 Single fuel engines

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

Chapter 11 FIRE SAFETY

11.1 Goal

The goal of this chapter is to provide fire protection, detection and fighting for all systems related to storing, handling, transfer and use of methyl/ethyl alcohol as fuel.

11.2 Functional requirements

This chapter is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.4**, **3.2.5**, **3.2.12**, **3.2.14** and **3.2.16**.

11.3 General requirements

The requirements in this chapter are additional to those given in **SOLAS chapter II-2**.

11.4 Fire protection

1 For the purposes of fire protection, fuel preparation spaces should be regarded as machinery space of category A. Should the space have boundaries towards other machinery spaces of category A, accommodation, control station or cargo areas, these boundaries should not be less than A-60.

2 Any boundary of accommodation up to navigation bridge windows, service spaces, control stations, machinery spaces and escape routes, facing fuel tanks on open deck should have A-60 fire integrity.

3 For fire integrity the fuel tank boundaries should be separated from the machinery spaces of category-A and other rooms with high fire risks by a cofferdam of at least 600 mm with insulation of not be less than A-60 class.

4 The bunkering station should be separated by A-60 class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

11.5 Fire main

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

11.6 Firefighting

1 Where fuel tanks are located on open deck, there should be a fixed fire-fighting system of alcohol resistant aqueous film forming foam (ARAFFF) type. The system should be operable from a safe position. The system should fulfil the requirements in **chapter 14** of the **FSS Code**.

2 The ARAFFF type foam fire-fighting should cover the area below the fuel tank where a large spill of fuel can be expected to spread.

3 The bunker station should have a fixed fire-extinguishing system of alcohol resistant aqueous film forming foam (ARAFFF) type and a portable dry chemical powder extinguisher or an equivalent extinguisher, located near the entrance of the bunkering station.

4 Where fuel tanks are located on open deck, there should be a fixed water spray system for diluting eventual large spills, cooling and fire prevention. The system should cover exposed parts of the fuel tank.

5 A fixed fire detection and fire alarm system complying with **FSS Code** should be provided for all compartments containing the methyl/ethyl alcohol fuel system.

6 Suitable detectors should be selected based on the fire characteristics of the fuel. Smoke detectors should be used in combination with detectors which can detect methanol/ethanol fire.

7 Means to ease detection and recognition of methyl/ethyl alcohols fires in machinery space should be provided for fire patrols and for fire-fighting purpose, such as portable heat-detection devices.

11.7 Extinguishing of engine-room and fuel preparation space

1 Machinery space and fuel preparation space where methyl/ethyl alcohol fuelled engines or fuel pumps are arranged should be protected by an approved fixed fire-extinguishing system in accordance with **SOLAS regulation II-2/10** and the **FSS Code**. In addition, the fire-extinguishing medium used should be suitable for the extinguishing of methyl/ethyl alcohol fires.

2 An approved alcohol resistant foam system covering the tank top and bilge area under the floor plates should be arranged for machinery space category A and fuel preparation space containing methyl/ethyl alcohol.

Chapter 12 EXPLOSION PREVENTION AND AREA CLASSIFICATION

12.1 Goal

The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects of a fire and explosion.

12.2 Functional requirements

This chapter is related to functional requirements **3.2.1**, **3.2.2**, **3.2.3**, **3.2.4**, **3.2.5**, **3.2.6**, **3.2.8**, **3.2.11**, **3.2.12**, **3.2.13**, **3.2.14**, **3.2.15** and **3.2.16** of these Guidelines.

1 The probability of explosions should be reduced to a minimum by:

(1) reducing the number of sources of ignition;

(2) reducing the probability of formation of ignitable mixtures; and

(3) the use of certified safe type electrical equipment suitable for the hazardous zone where the use of electrical equipment in hazardous areas is unavoidable.

12.3 General requirements

1 Hazardous areas on open deck and other spaces not addressed in this chapter should be analysed and classified based on a recognized standard. The electrical equipment fitted within hazardous areas should be according to the same standard.

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

2 All hazardous areas should be inaccessible to passengers and unauthorized crew at all times.

12.4 Area classification

1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2, according to **12.5**. In cases where the prescriptive provisions in **12.5** are deemed to be inappropriate, area classification according to IEC 60079-10 should be applied with special consideration by the Society.

Note: Refer to standards IEC 60079-10-1:2015 Explosive atmospheres Part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

3 Ventilation ducts should have the same area classification as the ventilated space.

12.5 Hazardous area zones

12.5.1 Hazardous area zone 0:

1 This zone includes, but is not limited to the interiors of methyl/ethyl fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing methyl/ethyl fuel.

12.5.2 Hazardous area zone 1

1 This zone includes, but is not limited to:

(1) cofferdams and other protective spaces surrounding the fuel tanks;

(2) fuel preparation spaces;

(3) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any methyl/ethyl fuel tank outlet, gas or vapour outlet, bunker manifold valve, other methyl/ethyl fuel valve, methyl/ethyl fuel pipe flange, methyl/ethyl fuel preparation space ventilation outlets;

(4) areas on open deck or semi-enclosed spaces on deck in the vicinity of the fuel tank P/V outlets, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet and within a hemisphere of 6 m radius below the outlet

(5) areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation space entrances, fuel preparation space ventilation inlets and other openings into zone 1 spaces;

(6) areas on the open deck within spillage coamings surrounding methyl/ethyl fuel bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(7) enclosed or semi-enclosed spaces in which pipes containing methyl/ethyl fuel are located, e.g. ducts around methyl/ethyl fuel pipes, semi-enclosed bunkering stations;

(8) a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

12.5.3 Hazardous area zone 2

1 This zone includes, but is not limited to:

(1) areas 4 m beyond the cylinder and 4 m beyond the sphere defined in **12.5.2-1(4)**

(2) areas within 1.5 m surrounding other open or semi-enclosed spaces of zone 1 defined in **12.5.2-1**; and

(3) airlocks.

Chapter 13 VENTILATION

13.1 Goal

The goal of this chapter is to provide for the ventilation required for safe working conditions for personnel and the safe operation of machinery and equipment where methyl/ethyl alcohol is used as fuel.

13.2 Functional requirements

This chapter is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.4**, **3.2.6**, and **3.2.11** to **3.2.16**.

13.3 General

1 Ventilation inlets and outlets for spaces required to be fitted with mechanical ventilation should be so located that according to International Load Line Convention they will not be required to have closing appliances.

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

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

4 Design of ventilation fans serving spaces where vapours from fuels may be present should fulfil the following:

(1) ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, should be of non-sparking construction defined as:

(2) impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

(3) impellers and housings of non-ferrous metals;

(4) impellers and housings of austenitic stainless steel;

(5) 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

(6) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

(7) In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm and

(8) Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

5 Ventilation systems required to avoid any vapour accumulation should consist of independent fans, each of sufficient capacity, unless otherwise specified in these Guidelines. The ventilation system should be of a mechanical exhaust type, with extraction inlets located such as to avoid accumulation of vapour from leaked methyl/ethyl alcohol in the space.

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

7 Air outlets from non-hazardous spaces should be located outside hazardous areas.

8 Air outlets from hazardous enclosed spaces should 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.

9 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.

10 Non-hazardous spaces with entry openings to a hazardous area should be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation should 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 should be required to:
  (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 should be monitored and in the event of failure of the overpressure ventilation:
  (a) an audible and visual alarm should be given at a manned location; and
  (b) if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard should be required.

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

11 Non-hazardous spaces with entry openings to a hazardous enclosed space should be arranged with an airlock and the hazardous space should be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space should be monitored and in the event of failure of the extraction ventilation:

(1) an audible and visual alarm should be given at a manned location; and

(2) if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to recognized standards in the non-hazardous space should be required.

12 Double bottoms, cofferdams, duct keels, pipe tunnels, hold spaces and other spaces where methyl/ethyl fuel may accumulate should be capable of being ventilated to ensure a safe environment when entry into the spaces is necessary.

13.4 Fuel preparation spaces

1 Fuel preparation spaces should be provided with an effective mechanical forced ventilation system of extraction type. During normal operation the ventilation should be at least 30 air changes per hour.

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

3 Ventilation systems for fuel preparation spaces and other fuel handling spaces should be in operation when pumps or other fuel treatment equipment are working.

13.5 Bunkering station

Bunkering stations that are not located on open deck should be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, the bunkering stations should be subject to special consideration with respect to provisions for mechanical ventilation. The Society may require special risk assessment.

13.6 Ducts and double wall pipes

1 Ducts and double wall pipes containing fuel piping fitted with mechanical ventilation system of the extraction type, should be provided with a ventilation capacity of at least 30 air changes per hour.

2 The ventilation system for double wall piping and ducts should be independent of all other ventilation systems.

3 The ventilation inlet for the double wall piping or duct should always be located in a non-hazardous area, in open air, away from ignition sources. The inlet opening should be fitted with a suitable wire mesh guard and protected from ingress of water.

Chapter 14 ELECTRICAL INSTALLATIONS

14.1 Goal

The goal of this chapter is to provide for electrical installations that minimizes the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

This chapter is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.3**, **3.2.5**, **3.2.8**, **3.2.11**, **3.2.13**, **3.2.15**, **3.2.16** and **3.2.17**.

14.3 General

1 Electrical installations should comply with a recognized standard at least equivalent to those acceptable to the Society.

Note: Refer to IEC 60092 series standards, as applicable.

2 Electrical equipment or wiring should not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

3 Where electrical equipment is installed in hazardous areas as provided in **14.3.2** it should be selected, installed and maintained in accordance with IEC standards or other standards at least equivalent to those acceptable to the Society.

4 The lighting system in hazardous areas should be divided between at least two branch circuits. All switches and protective devices should interrupt all poles or phases and should be located in a non-hazardous area.

5 The installation on board of the electrical equipment units should be such as to ensure the safe bonding to the hull of the units themselves.

Chapter 15 CONTROL, MONITORING AND SAFETY SYSTEMS

15.1 Goal

The goal of this chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the fuel installations as covered in the other chapters of these Guidelines.

15.2 Functional requirements

This chapter is related to functional requirements in **3.2.1**, **3.2.2**, **3.2.3**, **3.2.9**, **3.2.10**, **3.2.11**, **3.2.13**, **3.2.14** and **3.2.17.** In particular, the following apply:

1 The control, monitoring and safety systems of the methyl/ethyl alcohol installations should be so arranged that there is not an unacceptable loss of power in the event of a single failure;

2 A fuel safety system should be arranged to close down the fuel supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention; .

3 The safety functions should be arranged in a dedicated fuel safety system that is independent of the fuel control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

4 The safety systems including the field instrumentation should be arranged to avoid spurious shutdown, e.g. as a result of a faulty vapour detector or a wire break in a sensor loop; and

5 Where two fuel supply systems are required to meet the requirements, each system should be fitted with its own set of independent fuel control and safety systems.

15.3 General requirements

1 Suitable instrumentation devices should be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel equipment including bunkering.

2 Liquid leakage detection should be installed in the protective cofferdams surrounding the fuel tanks, in all ducts around fuel pipes, in fuel preparation spaces, and in other enclosed spaces containing single walled fuel piping or other fuel equipment.

3 The annular space in a double walled piping system should be monitored for leakages and the monitoring system should be connected to an alarm system. Any leakage detected should lead to shutdown of the affected fuel supply line in accordance with **table 15.1**.

4 At least one bilge well with a level indicator should be provided for each enclosed space, where an independent storage tank without a protective cofferdam is located. A high-level bilge alarm should be provided. The leakage detection system should trigger an alarm and the safety functions in accordance with **table 15.1**.

5 For tanks not permanently installed in the vessel a monitoring system equivalent to that provided for permanent installed tanks should be provided.

15.4 Bunkering and fuel tank pipe monitoring

15.4.1 Level indicators for fuel tanks

Each fuel tank should be fitted with closed level gauging devices, arranged to ensure a level reading is always obtainable and unless any necessary maintenance can be carried out while the fuel tank is in service, two devices should be installed

15.4.2 Overflow control

1 Each fuel tank should be fitted with a visual and audible high level alarm. This should be able to be function tested from the outside of the tank and can be common with the level gauging system (configured as an alarm on the gauging transmitter), but should be independent of the high-high level alarm;

2 An additional sensor (high-high level) operating independently of the high liquid level alarm should automatically actuate a shut-off valve to avoid excessive liquid pressure in the bunkering line and prevent the tank from becoming liquid full; and

3 The high and high-high level alarm for the fuel tanks should be visual and audible at the location at which gas-freeing by water filling of the fuel tanks is controlled, given that water filling is the preferred method for gas-freeing.

15.5 Bunkering control

1 Bunkering control should be from a safe remote location. At this safe remote location:

(1) Tank level should be capable of being monitored.

(2) The remote control valves required by **8.5.3** should be capable of being operated from this location. Closing of the bunkering shutdown valve should be possible from the control location for bunkering and from another safe location; and

(3) Overfill alarms and automatic shutdown should also be indicated at this location.

2 If the ventilation in the ducting enclosure or annular spaces of the double walled bunkering lines stops, an audible and visual alarm should be activated at the bunkering control location.

3 If fuel leakage is detected in ducting enclosure or the annular spaces of the double walled bunkering lines an audible and visual alarm and emergency shutdown of the bunkering valve should automatically be activated.

15.6 Engine monitoring

1 In addition to the instrumentation provided in accordance with **SOLAS chapter II-1**, **part C**, indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

(1) operation of methyl/ethyl alcohol fuel engines; and

(2) operation and mode of operation of the engine in the case of dual fuel engines.

15.7 Gas detection

1 Permanently installed gas detectors should be fitted in:

(1) all ventilated annular spaces of the double walled fuel pipes;

(2) machinery spaces containing fuel equipment or consumers.;

(3) fuel preparation spaces;

(4) other enclosed spaces containing fuel piping or other fuel equipment without ducting;

(5) other enclosed or semi-enclosed spaces where fuel vapours may accumulate;

(6) cofferdams and fuel storage hold spaces surrounding fuel tanks;

(7) airlocks; and

(8) at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2.

2 The number and placement of detectors in each space should be considered taking into account the size, layout and ventilation of the space. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

3 Fuel vapour detection equipment should be designed, installed and tested in accordance with a recognized standard.

Note: Refer to IEC 60079-29-1 – Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable detectors.

4 An audible and visible alarm should be activated at a fuel vapour concentration of 20% of the lower explosion limit (LEL). The safety system should be activated at 40% of LEL at two detectors. Special consideration should be given to toxicity in the design process of the detection system.

5 For ventilated ducts and annular spaces around fuel pipes in the machinery spaces containing methyl/ethyl alcohol-fuelled engines, the alarm limit should be set to 20% LEL. The safety system should be activated at 40% of LEL at two detectors.

6 Audible and visible alarms from the fuel vapour detection equipment should be located on the navigation bridge in the continuously manned central control station, safety centre and at the control location for bunkering as well as locally.

7 Fuel vapour detection required by this section should be continuous without delay.

15.8 Fire detection

Fire detection in machinery space containing methyl/ethyl alcohol engines and fuel storage hold spaces should give audible and visual alarms on the navigation bridge and in a continuously manned central control station or safety centre as well as locally.

15.9 Ventilation

Any loss of the required ventilating capacity should give an audible and visual alarm on the navigation bridge and in a continuously manned central control station or safety centre as well as locally.

15.10 Safety functions of fuel supply systems

1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the fuel supply lines.

2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

3 A caution placard or signboard should be permanently fitted in the machinery space containing methyl/ethyl-fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, should not be done when the engine(s) is running on methyl/ethyl.

4 Pumps and fuel supply should be arranged for manual remote emergency stop from the following locations as applicable:

(1) navigation bridge;

(2) cargo control room;

(3) on-board safety centre;

(4) engine control room;

(5) fire control station; and

(6) adjacent to the exit of fuel preparation spaces.

Table 15.1 Monitoring of Methyl/Ethyl alcohol supply system to engines

Parameter	Alarm	Automatic Shutdown of tank valve (valves referred to in **9.6.2**)	Automatic shutdown of master fuel valve(valves referred to in **9.6.3**)	Automatic shutdown of bunkering valve	Comments
High-level fuel tank	X			X	See **15.4.2.1**
High, high-level fuel tank	X			X	See **15.4.2.2** & **15.5.1**
Loss of ventilation in the annular space in the bunkering line	X			X	See **15.5.2**
Gas detection in the annular space in the bunkering line	X			X	See **15.5.3**
Loss of ventilation in ventilated areas	X				See **15.9**
Manual shutdown				X	See **15.5.1**
Liquid methyl/ethyl alcohol detection in the annular space of the double walled bunkering line	X			X	See **15.5.3**
Vapour detection in ducts around fuel pipes	X				See **15.7.1.1**
Vapour detection in cofferdams surrounding fuel tanks. One detector giving 20% of LEL	X				See **15.7.4**
Vapour detection in airlocks	X				See **15.7.1.7**
Vapour detection in cofferdams surrounding fuel tanks. Two detectors giving 40% of LEL	X	X		X	See **15.7.4**
Vapour detection in ducts around double walled pipes , 20% of LEL	X				See **15.7.5**
Vapour detection in ducts around double walled pipes,40% of LEL	X	X	X		See **15.7.5** Two gas detectors to give min. 40% LEL before shutdown.
Liquid leak detection in annular space of double walled pipes	X	X	X		See **15.3.2**

Parameter	Alarm	Automatic Shutdown of tank valve (valves referred to in **9.6.2**)	Automatic shutdown of master fuel valve(valves referred to in **9.6.3**)	Automatic shutdown of bunkering valve	Comments
Liquid leak detection in engine room	X	X	X		See **15.3.2**
Liquid leak detection in fuel preparation space	X	X			See **15.3.2**
Liquid leakage detection in Protective cofferdams surrounding fuel tanks	X				See **15.3.2**

Chapter 16 DRILLS AND EMERGENCY EXERCISES

16.1 Goal

The goal of this section is to ensure that seafarers on board ships to which these Guidelines apply, are adequately qualified, trained and experienced.

1 Drills and emergency exercises on board should be conducted at regular intervals.

2 Exercises related to low-flashpoint fuels, such as methyl/ethyl alcohol should at least include following:

(1) tabletop exercise;

(2) review of fueling procedures based in the fuel handling manual required by **17.2.3**;

(3) responses to potential contingences;

(4) tests of equipment intended for contingency response; and

(5) reviews that assigned seafarers are trained to perform assigned duties during fueling, operation and contingency response.

3 Low-flashpoint fuel related exercises should be incorporated into periodical drills required by **regulation II-2/15** of the **SOLAS Convention**, as amended

4 The response and safety system for hazards and accident control should be reviewed and tested.

5 All staff onboard should be trained as per **STCW**.

6 The master, officers, ratings and other personnel on ship using low-flashpoint fuels should be trained and qualified in accordance to the regulation **V/3** of the **STCW Convention** and Section **A-V/3** of the **STCW Code** taking into account the specific hazardous of the methyl/ethyl alcohol used as fuel.

Chapter 17 OPERATION

17.1 Goal

The goal of this section is to ensure that operational procedures for the loading, storage, operation, maintenance and inspection of systems for methanol/ethanol 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 these fuels.

17.2 Functional requirements

This chapter relates to the functional requirements in **3.2.1** to **3.2.3**, **3.2.9**, **3.2.11**, **3.2.14**, **3.2.15** and **3.2.16**. In particular the following apply:

1 a copy of these Guidelines, or national regulations incorporating the provisions of the same, should be on board every ship covered by these Guidelines;

2 maintenance procedures and information for all methanol/ethanol related installations should be available on board;

3 the ship should be provided with operational procedures including a suitably detailed fuel handling manual, such that trained qualified personnel can safely operate the fuel bunkering, storage and transfer systems; and

4 the ship should be provided with suitable emergency procedures.

17.3 Requirements for maintenance

1 Maintenance and repair procedures should include considerations with respect to the fuel containment system and adjacent spaces. Special consideration should be given to the toxicity of fuel.

2 The procedures and information should include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a standard recognized by the Society.

17.4 Requirements for bunkering operations

17.4.1 Responsibilities

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) should:

(1) agree in writing the transfer procedure including the maximum transfer rate at all stages and volume to be transferred;

(2) agree in writing action to be taken in an emergency; and

(3) complete and sign the bunker safety checklist.

2 Upon completion of bunkering operations, the ship PIC should receive and sign documentation containing a description of the product and the quantity delivered.

17.4.2 Overview of control, automation and safety systems

1 The fuel handling manual required by **17.2.3** should include but is not limited to:

(1) overall operation of the ship from dry-dock to dry-dock, including procedures for bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing;

(2) operation of inert gas systems;

(3) fire-fighting and emergency procedures: operation and maintenance of fire-fighting systems and use of extinguishing agents;

(4) specific fuel properties and special equipment needed for the safe handling of the particular fuel;

(5) fixed and portable gas detection operation and maintenance of equipment;

(6) emergency shutdown systems, where fitted; and

(7) a description of the procedural actions to take in an emergency situation, such as leakage, fire or poisoning.

2 A fuel system schematic/piping and instrumentation diagram (P&ID) should be reproduced and permanently displayed in the ship's bunker control station and at the bunker station.

17.4.3 Pre-bunkering verification

1 Prior to conducting bunkering operations, pre-bunkering verification including, but not limited to the following, should be carried out and documented in the bunker safety checklist:

(1) all communications methods, including ship shore link (SSL), if fitted;

(2) operation of fixed fire detection equipment;

(3) operation of portable gas detection equipment

(4) readiness of fixed and portable fire-fighting systems and appliances;

(5) operation of remote controlled valves; and

(6) inspection of hoses and couplings.

2 Documentation of successful verification should be indicated by the mutually agreed and executed bunkering safety checklist signed by both PICs.

17.4.4 Ship bunkering source communications

1 Communications should 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 should 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 PICs should 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, should be compatible with the receiving ship and the delivering facility ESD system.

Note: Refer to ISO 28460, Petroleum and natural gas industries – installation and equipment for liquefied natural gas – Ship-to-shore interface and port operations.

17.4.5 Electrical bonding

Consideration should be given to the electrical insulation between ship and shore

Part B

Guidelines for Ships Using LPG as Fuel

CONTENTS

Chapter 1 PREAMBLE 1
Chapter 2 GENERAL 2
2.1 Application 2
2.2 Definitions 2
2.3 Alternative design 2
Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS 3
3.1 Goal 3
3.2 Functional requirements 3
Chapter 4 GENERAL REQUIREMENTS 4
4.1 Goal 4
4.2 Risk assessment 4
4.3 Limitation of explosion consequences 4
Chapter 5 SHIP DESIGN AND ARRANGEMENT 5
5.1 Goal 5
5.2 Functional Requirements 5
5.3 General Requirements 5
5.4 Machinery Space Concepts 7
5.5 Gas Safe Machinery Space 7
5.6 Location and Protection of Fuel Piping 8
5.7 Fuel Preparation Room Design 8
5.8 Bilge Systems 8
5.9 Drip Trays 8
5.10 Arrangement of Entrances and Other Openings in Enclosed Spaces 9
5.11 Airlocks 9
Chapter 6 FUEL CONTAINMENT SYSTEM 11
6.1 Goal 11
6.3 General Requirements 11
6.4 Liquefied Gas Fuel Containment 12
6.5 Portable Liquefied Gas Fuel Tanks 36
6.7 Pressure Relief System 37
6.8 Loading Limit for Liquefied Gas Fuel Tanks 41
6.9 The Maintaining of Fuel Storage Condition 42
6.10 Atmospheric Control within the Fuel Containment System 43
6.11 Atmosphere Control within Fuel Storage Hold Spaces (Fuel Containment Systems other than Type C Independent Tanks) 43
6.12 Environmental Control of Spaces Surrounding Type C Independent Tanks 44
6.13 Inerting 44
6.14 Inert Gas Production and Storage on Board 44
Chapter 7 MATERIAL AND GENERAL PIPE DESIGN 46
7.1 Goal 46
7.2 Functional Requirements 46
7.3 General Pipe Design 46

7.4 Requirements for Materials 49
Chapter 8 BUNKERING 57
8.1 Goal 57
8.2 Functional Requirements 57
8.3 Bunkering Station 57
8.4 Manifold 57
8.4.1 Manifolds 57
8.5 Bunkering System 58
Chapter 9 FUEL SUPPLY TO CONSUMERS 59
9.1 Goal 59
9.2 Functional Requirements 59
9.3 Redundancy of Fuel Supply 59
9.4 Safety Functions of Gas Supply System 59
9.5 Fuel Distribution Outside of Machinery Space 61
9.6 Fuel Supply to Consumers in Gas-safe Machinery Spaces 61
9.7 The Design of Ventilated Duct, Outer Pipe against Inner Pipe Gas Leakage 62
9.8 Compressors and Pumps 63
Chapter 10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS 64
10.1 Goal 64
10.2 Functional Requirements 64
10.3 Internal Combustion Engines of Piston Type 64
10.4 Main and Auxiliary Boilers 66
Chapter 11 FIRE SAFETY 68
11.1 Goal 68
11.2 Functional Requirements 68
11.3 Fire Protection 68
11.4 Fire Main 68
11.5 Water Spray System 69
11.6 Dry Chemical Powder Fire-extinguishing System 69
11.7 Fire Detection and Alarm System 69
Chapter 12 EXPLOSION PREVENTION 70
12.1 Goal 70
12.2 Functional Requirements 70
12.3 General 70
12.4 Hazardous Areas 70
12.5 Hazardous Area Zones 71
Chapter 13 VENTILATION 72
13.1 Goal 72
13.2 Functional requirements 72
13.3 General Requirements 72
13.4 Tank Connection Space 74
13.5 Machinery Spaces 74
13.6 Fuel Preparation Room 74
13.7 Bunkering Station 75
13.8 Ducts and Double Pipes 75

Chapter 14 ELECTRICAL INSTALLATIONS ... 76
14.1 Goal ... 76
14.2 Functional Requirements ... 76
14.3 General Requirements ... 76
Chapter 15 CONTROL, MONITORING AND SAFETY SYSTEMS ... 78
15.1 Goal ... 78
15.2 Functional Requirements ... 78
15.3 General ... 78
15.4 Bunkering and Liquefied Gas Fuel Tank Monitoring ... 78
15.5 Bunkering Control ... 80
15.6 Gas Compressor Monitoring ... 81
15.7 Gas Engine Monitoring ... 81
15.8 Gas Detection ... 81
15.9 Fire Detection ... 82
15.10 Ventilation ... 82
15.11 Safety Functions of Fuel Supply Systems ... 83
Chapter 16 MANUFACTURE, WORKMANSHIP AND TESTING ... 87
16.1 General ... 87
16.2 General Test Requirements and Specifications ... 87
16.3 Welding of Metallic Materials and Non-destructive Testing for the Fuel Containment System ... 89
16.4 Other Requirements for Construction in Metallic Materials ... 92
16.5 Testing ... 92
16.6 Welding, Post-weld Heat Treatment and Non-destructive Testing ... 94
16.7 Testing ... 95
Chapter 17 OPERATING REQUIREMENTS ... 97
17.1 Goal ... 97
17.2 Functional Requirements ... 97
17.3 Fuel Handling Manual and Mounting ... 97
17.4 Maintenance and Repair Procedures ... 98
17.5 Operating Requirements ... 98
Chapter 18 USE OF CARGO AS FUEL ... 101
18.1 General ... 101
18.2 Use of LPG as Fuel ... 101
18.3 Arrangement of Spaces Containing LPG Fuel Consumers ... 101
18.4 LPG Fuel Supply ... 102
18.5 LPG Fuel Plants and Related Storage Tanks ... 104
18.6 Special Requirements for Main Boilers and Gas Combustion units ... 107
18.7 Special Requirements for LPG fired Internal Combustion Engines ... 107
18.8 Operating Requirements ... 109

Chapter 1 PREAMBLE

These guidelines provide provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using LPG as fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved..

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

Chapter 2 to **17** of these guidelines are based on IGF Code. **Chapter 2** to **4** provide functional requirements and general requirements for ships using low-flashpoint fuel (except for liquefied gas carriers) and **Chapter 5** to **17** separately provide special requirements **Part B-1** which apply to ships using LPG as fuel. On the other hand, **Part B-2** of these guidelines provide the safety requirements based on Chapter 16 of IGC Code which apply to liquefied gas carriers using LPG as fuel in addition to the relevant requirements of IGC Code.

Part B-1 Requirements for the Safety of Ships Using LPG as Fuel

Chapter 2 GENERAL

2.1 Application

1 **Chapter 2** to **17** of these Guidelines apply to ships using LPG as fuel (except for liquefied gas carriers).

2 The requirements in these Guidelines are specified on the premise of application to the ships to which SOLAS Convention applies. However, if it is difficult to comply with the requirements of these Guidelines due to the size of the ships, etc., special considerations may be given to the conditions provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

2.2 Definitions

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2 and **2.2, Part GF of the Rules for the Survey and Construction of Steel Ships.**

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

2 *LPG* means liquefied petroleum gas. The main chemical composition of LPG is propane (C_3H_8), (normal-/iso-)butane (C_4H_{10}) or a mixture of propane and butane.

3 *Single failure* is where loss of intended function occurs through one fault or action.

4 *Fuel* means methyl/ethyl alcohol fuels or LPG, containing allowable additives or impurities, suitable for the safe operation on board ships, complying with an international standard.

2.3 Alternative design

1 These Guidelines contains functional requirements for all appliances and arrangements related to the usage of LPG fuels.

2 Appliances and arrangements of LPG fuel systems may deviate from those set out in these Guidelines, provided such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

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

Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of these Guidelines 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 LPG as fuel.

3.2 Functional requirements

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

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

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

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

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

6 Unintended accumulation of explosive, flammable or toxic vapour and liquid concentrations should be prevented.

7 System components should be protected against external damage.

8 Sources of ignition in hazardous areas should be minimized to reduce the probability of fire and explosions.

9 Safe and suitable fuel supply, storage and bunkering arrangements should be provided, capable of receiving and containing the fuel in the required state without leakage.

10 Piping systems, containment and overpressure relief arrangements that are of suitable design, material, construction and installation for their intended application should be provided.

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

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

13 Fixed fuel vapour and/or leakage detection suitable for all spaces and areas concerned should be arranged.

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

15 Commissioning, trials and maintenance of fuel systems and fuel utilization machinery should satisfy the goal in terms of safety, availability and reliability.

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

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

Chapter 4 GENERAL REQUIREMENTS

4.1 Goal

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

4.2 Risk assessment

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

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

4.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release1 and potential ignition sources should not:

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

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

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

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

5 damage life-saving equipment or associated launching arrangements;

6 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;

7 affect other areas of the vessel 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 (LSA) or impede escape routes.

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

Chapter 5 SHIP DESIGN AND ARRANGEMENT

5.1 Goal

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

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 **3.2.14** and **3.2.16**. 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 led 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

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.

Note: Arrangement of vent post, equipment, ventilation, opening and restricted area is to be taken into account the specific gravity of LPG/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, $0.75 + Vc \times 0.2 / 4{,}000\ m$;

iii) for 5,000m^3 ≤ V_c < 30,000m^3, $0.8 + Vc / 25{,}000\ m$; and

iv) for V_c ≥ 30,000m^3, 2m,

where:

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

(5) The lowermost boundary of the fuel tank(s) 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 requirements 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 $x1$ is to correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of $x2$ 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.

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

f_v: calculated by following formulation:

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

$f_v = 0.2 - (0.2 \cdot ((H - d) - 7.8)/4.7)$, in all other cases f_v 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, $0.75 + Vc \times 0.2 / 4{,}000$ m;

iii) for 5,000m^3 ≤ V_c < 30,000m^3, $0.8 + Vc / 25{,}000$ 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°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 requirements 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

5.4.1 General

In order to minimize the probability of a gas explosion in gas safe machinery spaces may be applied following (1) :

(1) 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.

5.5 Gas Safe Machinery Space

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 Location and Protection of Fuel Piping

5.6.1 Distance from the Ship's Side

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

5.6.2 Piping

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

5.6.3 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 Fuel Preparation Room Design

1 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.

2 LPG fuel preparation room is to be provided with a ventilation system suitable for handling LPG fuel gas in the event of LPG fuel leakage.

3 LPG fuel preparation room is to be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

5.8 Bilge Systems

5.8.1 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.

5.8.2 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.

5.8.3 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.

5.9 Drip Trays

5.9.1 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.

Note: The place of high pressure LPG fuel leakage is to be taken into effect of expansion of high pressure LPG fuel such as low temperature.

5.9.2 Materials

Drip trays are to be made of suitable material.

5.9.3 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.

5.9.4 Drain Valves

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

5.9.5 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.

5.9.6 Alarm and safety device

Drip trays are to be fitted with means for detecting a leakage and activate the safety systems.

5.10 Arrangement of Entrances and Other Openings in Enclosed Spaces

5.10.1 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 **5.11** is to be provided.

5.10.2 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.

5.10.3 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.

5.10.4 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.

5.11 Airlocks

5.11.1 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.

5.11.2 Mechanical Ventilations

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

5.11.3 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**.

5.11.4 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^2. Airlocks are not to be used for other purposes, for instance as store rooms.

5.11.5 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.

5.11.6 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.

5.11.7 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

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

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 3.2.16**.In addition, **6.2.2** applies.

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

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.

Note: Means are to be provided whereby LPG/gas in the fuel tank and the fuel piping systems can be safely emptied by taking into account the physical properties of LPG.

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

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 6.1 Tank Type and Secondary Barrier

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

6.4.4 Design of Secondary Barriers

The design of the secondary barrier, including spray shield if fitted, 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 degrees.

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 requirements 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 requirements 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:

$$P_{eq1} = P_0 + (P_{gd})\max\ (MPa)$$

$$P_{eq2} = P_h + (P_{gd}site)\max\ (MPa)$$

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_β : dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β ; (see **Fig. 6.1**). For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, should be used.

z_β : largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see **Fig. 6.2**). Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining z_β unless the total volume of tank domes V_d does not exceed the following value:

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

where:

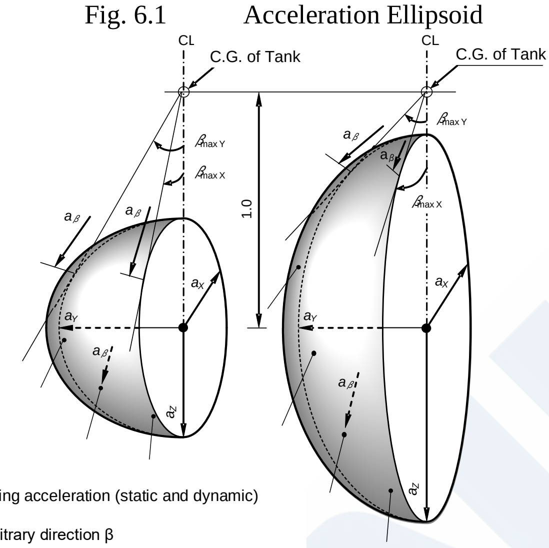
V_t : tank volume without any domes; and

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

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

The direction that gives the maximum value $(P_{gd})max$ or $(P_{gd}site)max$ 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. 6.1**. The above formula applies only to full tanks.

Fig. 6.1 Acceleration Ellipsoid



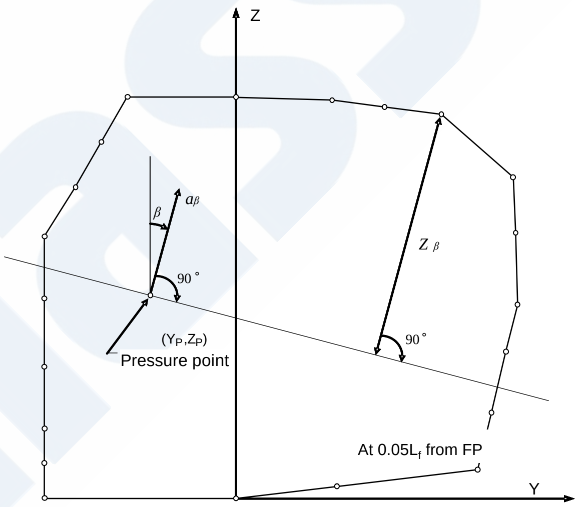
α_β : resulting acceleration (static and dynamic)
in arbitrary direction β

α_x : longitudinal component of acceleration

α_y : transverse component of acceleration

α_z : vertical component of acceleration (refer to

Fig. 6.2 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

i) Transient thermally induced loads during cooling down periods are to be considered for tanks intended for liquefied gas fuel temperatures below -55°C.

ii) 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 degrees 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 it's 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 6.2** in forward direction and "*a* /2" in the aft direction, where "*g*" is gravitational acceleration.

Table 6.2 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:

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

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

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

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

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

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

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

$\sigma_{x \cdot dyn}$, $\sigma_{y \cdot dyn}$, $\sigma_{z \cdot dyn}$, $\tau_{xy \cdot dyn}$, $\tau_{xz \cdot dyn}$ and $\tau_{yz \cdot dyn}$ 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 σ_c (von Mises, Huber) is to be determined by:

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

where:

σ_x : total normal stress in X-direction;

σ_y : total normal stress in Y-direction;

σ_z : total normal stress in Z-direction;

τ_{xy} : total shear stress in X -Y plane;

τ_{xz} : total shear stress in X -Z plane; and

τ_{yz} : total shear stress in Y-Z plane.

The above values 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:

$$\Sigma \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \le C_w$$

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 requirements 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.

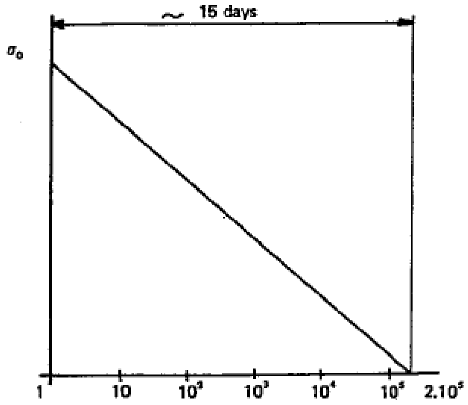
Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, is not to be less than three times the inspection interval.

(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. 6.3 Simplified Load Distribution



Response cycles

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

(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 requirements 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 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 σ_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 *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:

σ_m : equivalent primary general membrane stress;

σ_L : equivalent primary local membrane stress;

σ_b : equivalent primary bending stress;

σ_g : equivalent secondary stress;

f: the lesser of R_m/A or R_e/B; and

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

with R_m and R_e as defined in **6.4.12(1)(a)iii)**. With regard to the stresses σ_m, σ_L, σ_b and σ_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 6.3 Values of *A*, *B*, *C* and *D* (Type *B*, Independent Tanks)

	Nickel steels and carbon manganese steels	Austenitic steel	Aluminium allloys
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 6.3** 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:

i) for nickel steels and carbon-manganese steels, the lesser of $R_m/2$ or $R_e/1.2$;

ii) for austenitic steels, the lesser of $R_m/2.5$ or $R_e/1.2$; and

iii) 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:

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

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

where:

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

with:

σ_m : design primary membrane stress;

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

$55 N/mm^2$: for ferritic-perlitic, martensitic and austenitic steel;

$25 N/mm^2$: for aluminium alloy (5083-0);

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

h, 0.75*b* or 0.45 *l* ,

with:

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

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

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

ρ_r : the relative density of the cargo ($\rho_r = 1$ 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:

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

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

with R_m and R_e as defined in **6.4.12(1)(a)iii)**. With regard to the stresses σ_m, σ_L, σ_b and σ_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 allloys
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
i) For type *C* independent tanks where the liquefied gas fuel at atmospheric pressure is below -55°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.
ii) 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
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 **6.4.15-3(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

(a) 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.

(b) 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 *MPa*. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_0 may be increased to a higher value but less than 0.070 *MPa*.

(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 *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 requirements 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 requirements 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 requirements 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 requirements 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 requirements.

(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

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**.

6.7 Pressure Relief System

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 17**);

(2) the procedures are to allow only one of the installed *PRVs* for the liquefied gas fuel tanks to be isolated, physical interlocksare 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.

Note: Structure of vent system and arrangement of vent exits with **6.7.2-7** and **6.7.2-9** is to be assessed by gas dispersal analysis or a physical test but for other exceptional cases alternative arrangements considered by the Society and Administration may be accepted.

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 degrees list and $0.015L_f$ 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:

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

where

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

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

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

$F = 0.5$: for tanks above the deck when insulation is approved by the 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. 6.4**.

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:

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

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

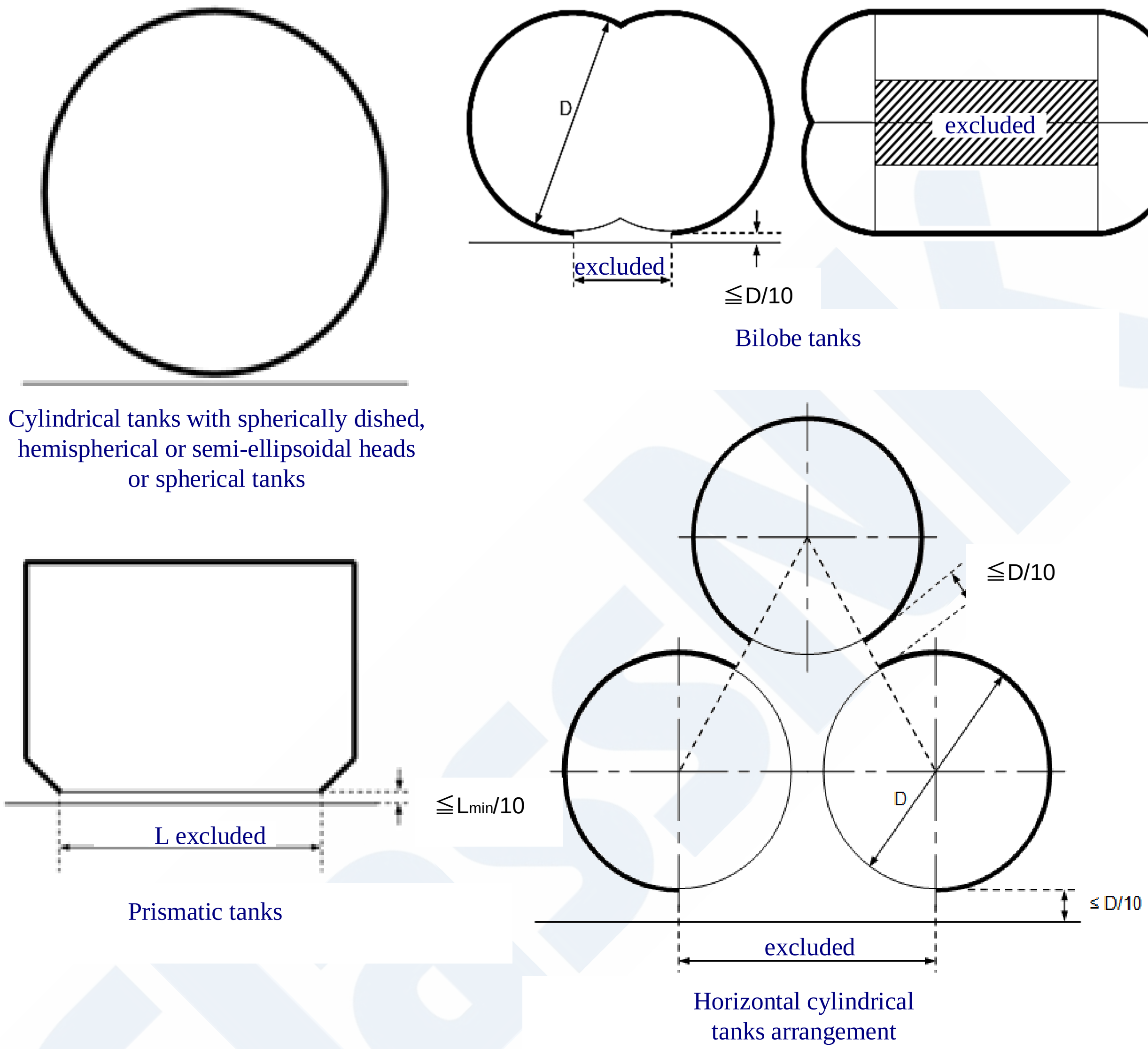
ii) for balanced *PRVs*: 30% of *MARVS*; and

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. 6.4 How to Determine External Surface Areas of Tanks



6.8 Loading Limit for Liquefied Gas Fuel Tanks

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 %
ρ_R :relative density of fuel at the reference temperature
ρ_L : relative density of fuel at the loading temperature

1 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

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

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.

Note: Means are to be provided whereby LPG/gas in the fuel tank and the fuel piping systems can be safely emptied by taking into account the physical properties of LPG.

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

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

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

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

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

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

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.

Note: 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.

5 LPG fuel supply system is to be non-accumulation of gases by take into account the LPG characteristics.

7.3 General Pipe Design

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.

6 The pipe and duct of high pressure LPG/gas leakage or release is to be taken into effect of expansion of high pressure LPG fuel such as low temperature.

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^2) 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:

$R_m/2.7$ 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.

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 Requirements for Materials

7.4.1 Metallic Materials

1 Materials for fuel containment and piping systems are to comply with the minimum requirements given in the following tables:
(1) **Table 7.1**: Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.
(2) **Table 7.2**: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C.
(3) **Table 7.3**: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C.
(4) **Table 7.4**: Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to -165°C.
(5) **Table 7.5**: 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 requirements for pipe materials in **Table7.4**.

5 The outer pipe or duct around liquefied gas fuel pipes is to fulfil the material requirements for pipe materials with design temperature down to -165°C in **Table 7.4**.

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: *KL*33-50*T*. -0*T* as suffix for 0°C.)

Table 7.1 Plates, Pipes (Seamless and Welded)(1),(2), Sections and Forgings for Fuel Tanks and Process Pressure Vessels for Design Temperatures not Lower than 0°C

CHEMICAL COMPOSITION AND HEAT TREATMENT

Carbon-manganese steel		
Fully killed fine grain steel		
Small additions of alloying elements by agreement with the Society		
Composition limits to be approved by the Society		
Normalized, or quenched and tempered(4)		
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
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^2(5)	
Toughness (Charpy *V* -notch impact test)		
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27 *J*	
Sections and forgings	Longitudinal test pieces. Minimum average energy value (*KV*) 41 *J*	
Test temperature	Thickness (*mm*)	Test temperature(℃)
	$t \leq 20$	0
	$20 < t \leq 40$ (3)	-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^2 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 7.2 Plates, Sections and Forgings(1) for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below 0°C and down to -55°C
(Maximum Thickness 25 *mm*(2))

Chemical composition and heat treatment				
Carbon-manganese steel (Fully killed, aluminium treated fine grain steel)				
Chemical composition (ladle analysis)				
C	M_n	S_i	*S*	*P*
0.16% max (3)	0.7~1.60%	0.10~0.50%	0.025% max	0.025% max
Optional additions : Alloys and grain refining elements may be generally in accordance with the following				
N_i	C_γ	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(4)				
Tensile and toughness (impact) test requirements				
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^2(5)			
Toughness (Charpy *V* -notch impact test) :				
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27*J*			
Sections and forgings	Longitudinal test pieces. Minimum average energy value (*KV*) 41*J*			
Test temperature	5°C below the design temperature or -20°C whichever is lower			

Notes

(1) The Charpy *V*-notch impact tests and chemistry requirements 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 (℃)
$25 < t \leq 30$	10℃ below design temperature or -20℃ whichever is lower
$30 < t \leq 35$	15℃ below design temperature or -20℃ whichever is lower
$35 < t \leq 40$	20℃ 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^2 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 7.3** may be necessary.

Table 7.3 Plates, Sections and Forgings(1) for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below -55°C and down to -165°C(2)
(Maximum Thickness 25 *mm*(3),(4))

Minimum design temp. (˚C)	Chemical composition(5) and heat treatment	Impact test temp. (˚C)
-60	1.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP(6)	-65
-65	2.25%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP(6)(7)	-70
-90	3.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP(6)(7)	-95
-105	5%nickel steel - normalized or normalized and tempered or quenched and tempered(6)(7)(8)	-110
-165	9%nickel steel - double normalized and tempered or quenched and tempered(6)	-196
-165	Austenitic stainless steels, such as types 304, 304*L*, 316, 316*L*, 321 and 347 solution treated(9)	-196
-165	Aluminium alloys(10): such as type 5083 annealed	Not required
-165	Austenitic *Fe*-*Ni* alloy (36% nickel) Heat treatment as agreed	Not required
Tensile and Toughness (Impact) Test Requirements: Sampling frequency: Plates: Each "piece" to be tested Sections and Forgings: Each "lot" to be tested Toughness (Charpy *V*- Notch Impact Test): Plates: Transverse test pieces. Minimum average energy value (*KV*) 27*J* Sections and Forgings: Longitudinal test pieces. Minimum average energy value (*KV*) 41*J*		

Notes

(1) The impact test required for forgings used in critical applications is to be subject to special consideration by the Society.

(2) The requirements 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 (℃)
$25 < t \leq 30$	10℃ below design temperature
$30 < t \leq 35$	15℃ below design temperature
$35 < t \leq 40$	20℃ below design temperature

In no case is the test temperature to be above that indicated in **Table 7.3**.
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 aluminimum alloys other than type 5083, additional tests may be required to verify the toughness of the material.

Table 7.4 Pipes (Seamless and Welded)(1), Forgings(2) and Castings(2) for Fuel and Process Piping for Design Temperatures below 0°C and down to -165°C(3)
(Maximum Thickness 25 *mm*)

Minimum design temp. (°C)	Chemical composition(5) 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.(6)	See note (4)	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered.(6)	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.(6)	-95	34
-165	9% nickel steel(7). Double normalized and tempered or quenched and tempered.	-196	41
	Austenitic stainless steels, such as types *304*, *304L*, *316*, *316L*, *321*, and *347*. Solution treated.(8)	-196	41
	Aluminium alloys(9); such as type 5083 annealed		Not required
Tensile and toughness (impact) test requirements 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 requirements for forgings and castings may be subject to special consideration by the Society.

(3) The requirements 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 aluminum alloys other than type 5083, additional tests may be required to verify the toughness of the material.

Table 7.5 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 -5 and above	In accordance with the relevant requirements in other Part							
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 **Table 7.2** except that the thickness limitation given in **Table 7.2** and in footnote 2 of that table does not apply.							

Note

×: means steel grade not to be used.

Chapter 8 BUNKERING

8.1 Goal

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

8.2.1 General

This chapter relates to functional requirements in **3.2.1** to **3.2.12** and **3.2.16.** 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

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 suctions 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 The bunkering station is to be arranged without low points or obstacles that could lead to LPG vapour accumulation.

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

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

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 are evaluated and approved.

Note: Arrangement of bunkering line is to be effectively performed inerting and gas-free by taking into account the physical properties of LPG.

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

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

9.2.1 General

This chapter is related to functional requirements in **3.2.1** to **3.2.6**, **3.2.8** to **3.2.16.** 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

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

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.

(3) When double block bleed valve is closed, LPG/gas between the double block bleed valves is automatically vented to a safe location in open air to be taking into account properties of LPG

Note: The bleed line of double block bleed valves is to be taken into effect of expansion of high pressure LPG/gas such as low temperature.

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

1 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.

2 Double block bleed valves and closable non-return valve between these valves and LPG fuel piping are to be provided to prevent back-flow of fuel vapour into the inert gas system.

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.

9.5 Fuel Distribution Outside of Machinery Space

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.

9.5.3 Control of LPG fuel system pressure and temperature

1 LPG systems are to be designed to prevent phase changes in the supply system up to the consumers

2 Where LPG fuel is intended to be used in the gaseous state and has a dew point higher than ambient temperature at the maximum expected pressure at the consumer inlet, the fuel is to be sufficiently heated and the fuel lines are to be properly heat traced.

3 Where LPG fuel is intended to be used in the liquid state, the pressure in the fuel manifold is to be sufficient to maintain the fuel in the liquid state.

9.6 Fuel Supply to Consumers in Gas-safe Machinery Spaces

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.

9.6.3 Mechanical Ventilation

The inlet and outlet of ventilation is to be arranged that released gas is led to a safe location in the open air without stagnation of LPG fuel.

Note: The inlet and outlet of ventilation is to be arranged to be taking into account LPG fuel piping and property of LPG/gas.

9.7 The Design of Ventilated Duct, Outer Pipe against Inner Pipe Gas Leakage

9.7.1 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.

9.7.2 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_4

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.

9.7.3 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.

9.7.4 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.

9.8 Compressors and Pumps

9.8.1 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.

9.8.2 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.

9.8.3 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.

9.8.4 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

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

10.2.1 General

This chapter is related to functional requirements in **3.2.1**, **3.2.11**, **3.2.12**, **3.2.15** and **3.2.16**. In addition, **10.2.2** applies.

10.2.2 Additional Requirements

1 The exhaust systems re 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

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.

8 LPG fuel injection valves are to be taking into account follows:

(1) LPG fuel injection valves are to possess satisfactory operating characteristics and durability for the assumed service period.

(2) LPG fuel injection valves are to be provided with sealing systems to effectively prevent gas fuel from leaking through spaces around valve spindles.

(3) LPG fuel injection valves are to be provided with effective cooling systems.

9 Gas Fuel Injection Valve Actuating Systems are to be taking into account follows:

(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.

10 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of LPG vapour accumulation in the crankcase is to be carried out and reflected in the safety concept of the engine.

11 The charge air system and is to be designed to prevent presence and possible accumulation of gaseous LPG.

12 The gas supply system for Otto cycle engines is to be designed to prevent condensation of LPG vapours.

13 The exhaust systems are to be configured to prevent any accumulation of un-burnt gaseous fuel.

14 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.

15 The connecting of gas piping and ducting to the gas injection valves are to be completely covered by continuous double piping construction or 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.

16 Suitable drainage arrangements for dealing with any leakage into secondary enclosure of LPG fuel system are to be provided.

17 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, Part GF of the Guidance of the Rules for the Survey and Construction of Steel Ships**

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.

Table10.1 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

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.

Chapter 11 FIRE SAFETY

11.1 Goal

The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of natural gas as ship fuel.

11.2 Functional Requirements

This chapter is related to functional requirements in **3.2.2**, **3.2.4**, **3.2.5**, **3.2.7**, **3.2.13**, **3.2.14** and **3.2.16**.

11.3 Fire Protection

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".

11.4 Fire Main

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

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

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.

3 Any space containing equipment for LPG fuel preparation such as pumps, compressors, heat exchangers, vaporizers and pressure vessels are to be regarded as a machinery space of category A for a fixed fire-extinguishing system specified **Chapter 25 Part R**. unless the space containing equipment for LPG fuel preparation room are provided with suitable explosion-protected.

11.7 Fire Detection and Alarm System

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

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

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

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**.

Note: Electrical equipment in hazardous area is taken into account physical properties of LPG/gas.

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**.

12.4 Hazardous Areas

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

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) 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

(8) 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

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

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 **3.2.13** and **3.2.16**.

13.3 General Requirements

13.3.1 Ventilation of Hazardous Areas

1 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.

2 Ventilation systems serving hazardous spaces are to be arranged to be led to a safe location to avoid accumulation of LPG vapour in case of LPG fuel gas leakage.

3 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**.

Note: The ventilation is to be arranged to be taking into account shape of spaces and property of LPG fuel. e.g. The air inlet of ventilation is arranged at upper part of enclosed space or semi-enclosed space. The air outlet of ventilation is arranged at lower part of enclosed space or semi-enclosed space.

4 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated. The means of closing are to be easily accessible as well as prominently and permanently marked and are to indicate whether the shutoff is open or closed.

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

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

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 Fans

The number and power of the ventilation fans 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

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

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

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

14.1.1 General

The goal of this chapter is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional Requirements

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**, **3.2.12** and **3.2.15** to **3.2.17**. 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

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.

Note: Hazardous area is to be decided by taking into account physical properties of LPG/gas

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-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

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

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 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.

4 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.

5 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

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

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 Permitable 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-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

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

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

15.7.1 Indicators

1 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.

Note: Instrumentation equipment are able to monitor LPG/gas phase state required by the engine.

2 When LPG fueled engines are operated on LPG fuel, exhaust gas temperatures at cylinder outlets shall be continuously monitored.

15.8 Gas Detection

15.8.1 Arrangements of Gas Detectors

1 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;

(10) at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in **4.2**

(11) enclosed and semi-enclosed bunkering stations; and

(12) other enclosed or semi-enclosed spaces where LPG fuel vapours may accumulate.

15.8.2 Number of Gas Detectors

The number of detectors in each space is to be considered taking into account the size and layout or the space. Gas dispersal analysis or a physical smoke test is to be used to find the best arrangement in cases where deemed necessary by the Society and Administration.

15.8.3 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.

15.8.4 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.

15.8.5 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 15.1**).

15.8.6 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 15.1**).

15.8.7 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.

15.8.8 Capability of Gas Detection

Gas detection required by this **15.8** is to be continuous without delay.

15.8.9 Portable gas detection equipment

At least two portable gas detectors capable of measuring LPG vapurs are to be provided. The detectors required to be provided by this section are according to a standard recognized by the Society.

Note: The wording standard recognized by the Society specified in above provision means those specified in IEC 60079-29-1.

15.9 Fire Detection

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 15.1** below.

15.10 Ventilation

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.

15.11 Safety Functions of Fuel Supply Systems

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

1 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.

2 A gas safety system is to be arranged to close down the gas supply system automatically, upon failure in systems as specified **15.2.2-2 of Part GF of the Rules for the Survey and Construction of Steel Ships** and as following **(1)** to **(4)**. For fuel-pump, compressor and LPG fuel system, arrangements are also to automatically shut down the motors in the event following **(1)** to **(4)**.

(1) Fire detection on deck or in LPG fuel preparation room
(2) Signal from ship/shore link
(3) Loss of motive power to ESD valves
(4) Main electric power failure

3 For LPG pump used when transferring from other LPG tank, arrangements are to be made to alarm in high-liquid level of LPG tank to be supplied and automatically shut down the motors in the event of high-high liquid level.

4 Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable, taking into account LPG characteristics.

Table 15.1 Monitoring of Gas Supply System to Engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection in tank connection space at 20% LEL	X			
Gas detection on two detectors[1)] in tank connection space at 40% LEL	X	X		
Fire detection in fuel storage hold space	X			
Fire detection in ventilation trunk to the tank connection space and in the tank connection space	X			
Bilge well high level in tank connection space	X			
Bilge well low temperature in tank connection space	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X [2)]		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X [2)]		
Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors1) in duct inside machinery space containing gas-fuelled engines at 60% LEL	X		X [3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	X			

Table 15.1Monitoring of Gas Supply System to Engines (continued)

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection on two detectors1) 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 [2)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5)]	X		X [3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	X		X	
Fire detection in machinery space containing gas-fuelled engines	X			
Abnormal gas pressure in gas supply pipe	X			
Failure of valve control actuating medium	X		X [4)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X [4)]	
Manually activated emergency shutdown of engine	X		X	

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

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 requirements may be modified at the discretion of the Society.

16.2 General Test Requirements and Specifications

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 requirements 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 **Table16.1**.

Table 16.1

Charpy *V* -notch specimen size	Minimum average energy of three specimens
10×10*mm*	*KV*
10×7.5*mm*	5/6*KV*
10×5.0*mm*	2/3*KV*

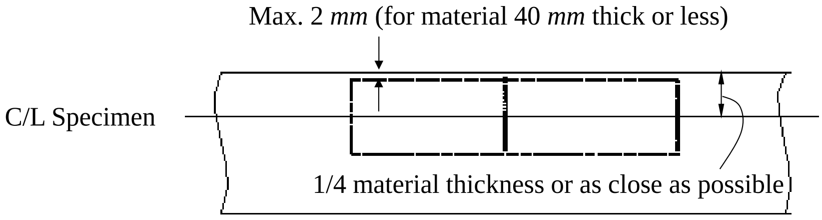
where:

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.

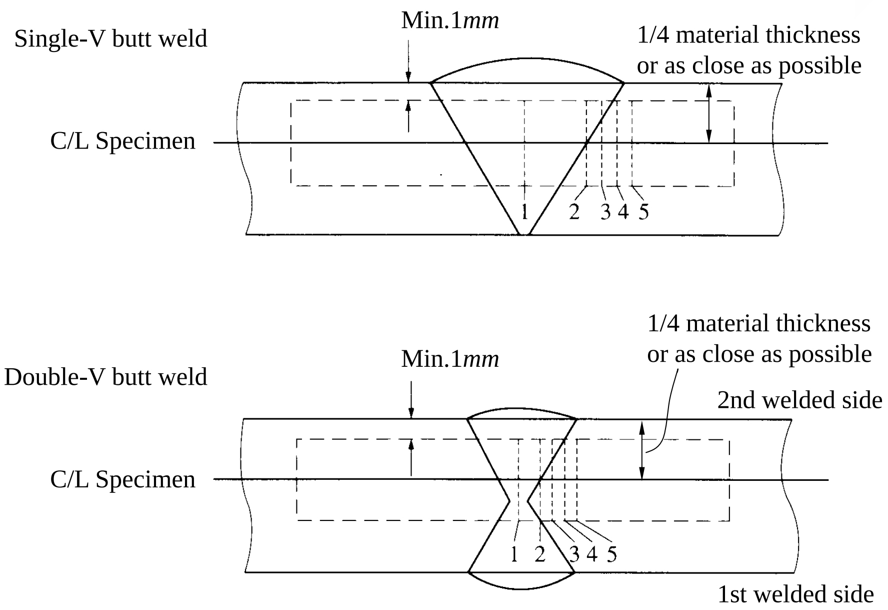
2 For base metal, the largest size Charpy *V*-notch impact test specimens possible for the material thickness are to be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in **Fig 16.1**.

Fig. 16.1 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. 16.2**, on the centreline of the welds, the fusion line and 1 *mm*, 3 *mm* and 5 *mm* from the fusion line.

Fig. 16.2 Orientation of Weld Test Specimen



Notch locations in **Fig. 16.2**:

1. centreline of the weld;
2. on fusion line;
3. in heat-affected zone (*HAZ*), 1 *mm* from fusion line;
4. in HAZ, 3 *mm* from fusion line; and
5. in HAZ, 5 *mm* from fusion line.

4 If the average value of the three initial Charpy *V*-notch impact test specimens fails to meet the stated requirements, 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

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. 16.2**:
 (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 requirements 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 degrees 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 27*J*. The weld metal requirements 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 requirements 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 requirement **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 requirements for membrane tanks are the same as the applicable test requirements 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 requirements 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 Requirements for Construction in Metallic Materials

16.4.1 General

Inspection and non-destructive testing of welds are to be in accordance with requirements 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 requirements 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

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 Requirements 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, requirement 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

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 **(d)**;

(a) design temperatures colder than minus 10°C; or

(b) design pressure greater than 1.0 *MPa*; or

(c) inside diameters of more than 75 *mm*; or

(d) 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 be 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 **(1)** to **(3)** above, 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

16.7.1 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.

16.7.2 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.

8 For LPG fuel supply system, performance verification tests may be required where deemed necessary by the Society.

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** and **3.2.14 to 3.2.16**. 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;
(9) A description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover;
(10) Operation of ventilations and dampers at each gas hazardous area; and
(11) Temperature and pressure control, alarm and safety systems of fuel containment system and fuel supply system.

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.

3 Before entering any space as possibility of leakages, the parsons in charge is to verify following

(1) Sufficient ventilation
(2) Alarm systems function properly for LPG gas detector and oxygen content measuring equipment
(3) Gas concentration and oxygen content (also record)

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.

3 Where deemed necessary by the Society and Administration beforehand, operational methods and procedure of gas free of LPG fuel system and LPG fuel tank before dry-docks is to be approved by the Society and Administration beforehand.

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.

Part B-2 Requirements for the Safety of Liquefied Gas Carriers Using LPG as Fuel

Chapter 18 USE OF CARGO AS FUEL

18.1 General

18.1.1 General Requirements

Notwithstanding the requirements of **Chapter 2** to **4** and **Chapter 5** to **17** of **Part B** in these guidelines, this part applies to liquefied gas carriers using LPG as fuel subject to the conditions specified in the following (1) and (2), instead of **16.2** to **16.8**, **Part N of the Rules**,.

(1) LPG carriers using their cargoes as fuel and complying with the requirements of Part N of the Rules; or

(2) Liquefied gas carriers using LPG as fuel provided that the fuel storage and distribution systems design and arrangements for LPG fuels comply with the requirements of Part N of the Rules.

In addition to application of these guidelines, for liquefied gas carriers using LPG as fuel, the same level of safety as natural gas in accordance with **Part N of the Rules** is to be demonstrated and approved by the administration.

18.2 Use of LPG as Fuel

This section addresses the use of LPG as fuel in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units and gas turbines of gas carriers.

18.2.1 Fuel Systems Supplying LPG

For vaporized LPG, the fuel supply system is to comply with the requirements of **18.4.1, 18.4.2** and **18.4.3.**

18.2.2 LPG Fuel Consumers

For vaporized LPG fuel consumers are to exhibit no visible flame and are to maintain the uptake exhaust temperature below autoignition point.

18.3 Arrangement of Spaces Containing LPG Fuel Consumers

18.3.1 Mechanical Ventilation System

1 Spaces containing LPG fuel supply equipment are to be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources.

2 Spaces containing LPG fuel supply equipment are to be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

18.3.2 Gas Detectors

1 Gas detectors are to be fitted in spaces containing LPG fuel supply equipment, particularly where air circulation is reduced. The gas detection system is to comply with the requirements of **Chapter 13, Part N of the Rules**.

18.3.3 Electrical Equipment Located in the Double Wall Pipe and Duct

Electrical equipment located in the double wall pipe or duct specified in **18.4.3** is to comply with the requirements of **Chapter 10, Part N of the Rules**.

18.3.4 Vents and Bleed Lines

All vents and bleed lines that may contain or be contaminated by LPG are to be routed to a safe location external to the machinery space and be fitted with a flame screen.

18.4 LPG Fuel Supply

18.4.1 General

1 The requirements of this section are to apply to LPG supply piping outside of the cargo area. LPG fuel piping is not to pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routing of the LNG pipeline is to take into account potential hazards, due to mechanical damage, in areas such as stores or machinery handling areas.

2 Provision is to be made for inerting and gas-freeing that portion of the LPG fuel piping systems located in the machinery space.

3 Double block and bleed valves and closable non-return valve between these valves and LPG fuel piping are to be provided to prevent back-flow of fuel vapour into the inert gas system

18.4.2 Leak Detection Countermeasure against Gas Leak

Continuous monitoring and alarms are to be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant LPG supply.

18.4.3 Routing of Fuel Supply Pipes

Fuel piping may pass through or extend into enclosed spaces other than those mentioned in **18.4.1**, provided it fulfils one of the following conditions:

(1) It is of a double-wall design with the space between the concentric pipes pressurized with inert gas at a pressure greater than LPG fuel pressure. The master gas fuel valve, as required by **18.4.6**, closes automatically upon loss of inert gas pressure; or

(2) It is installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air

changes per hour and is arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation is in accordance with **Chapter 12, Part N of the Rules**, as applicable. The ventilation is capable of being always in operation when there is fuel in the piping and the master gas fuel valve, as required by **18.4.6**, closes automatically if the required air flow is not established and maintained by the exhaust ventilation system. The ventilation is to be arranged that released gas is led to a safe location in the open air without accumulation between LPG fuel piping and outer pipe or the duct, taking into account LPG properties. The inlet or the duct is to be from a non-hazardous open deck, and the ventilation outlet is to be in a safe location.

18.4.4 Requirements for LPG Fuel with Pressure Greater than 1 *MPa*

1 Fuel delivery lines between the high pressure fuel pumps/compressors and LPG consumers are to be protected with a double-walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single-walled pipe in the cargo area up to the isolating valve(s) required by **18.4.6** is acceptable.

2 The arrangement in **18.4.3(2)** may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of **18.4.7** and taking into account the effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.

3 The pipe and duct which have the risk of low temperature exposure by high-pressure LPG/gas leakage or release is to take into account the effect of vaporization and expansion of high pressure LPG.

18.4.5 Gas Consumer Isolation

1 The LPG supply piping of each LPG fuel consumer unit is to be provided with gas fuel isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves are to be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one is not to affect the gas supply to the others.

2 When the double block and bleed valves are closed, appropriate means are to be automatically activated to vent accumulated LPG /gas between the two shutoff valves to a safe location in open air.

3 The bleed line of the double block and bleed valves is to be designed taking into account the effect of low temperature caused by high pressure LPG/gas expansion leakage.

18.4.6 Spaces Containing LPG Fuel Consumers

1 It is to be possible to isolate the LPG fuel supply to each individual space containing a LPG consumer(s) or through which LPG fuel supply piping is run, with an individual master valve, which is located within the cargo area. The isolation of LPG fuel supply to a space is not to affect the LPG supply to other spaces containing LPG fuel consumers if they are located in two or more spaces, and it is not to cause loss of propulsion or electrical power.

2 If the double barrier around the gas supply system is continuous, an individual master valve located in the cargo area may be provided for each LPG fuel consumer inside the space. The individual master valve is to operate under the following circumstances:

(1) automatically by:

(a) leak detection in the annular space of a double-walled pipe served by that individual master valve;

(b) leak detection in other compartments containing single-walled gas piping that is part of the supply system served by the individual master valve; and

(c) loss of ventilation or loss of pressure in the annular space of a double-walled pipe.

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

18.4.7 Piping and Ducting Construction

1 LPG fuel piping in machinery spaces is to comply with **5.1** to **5.9, Part N of the Rules**, as applicable. The piping is to, as far as practicable, have welded joints. Those parts of the LPG fuel piping that are not enclosed in a ventilated pipe or duct according to **18.4.3**, and are on the weather decks outside the cargo area, are to have full penetration butt-welded joints and are to be fully radiographed.

2 The connecting of LPG piping and ducting to LPG injection valves is to be a continuous double piping or 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 LPG pipes on the engine itself, until LPG fuel is injected into the chamber.

3 Suitable drainage arrangements for dealing with any leakage into secondary enclosure of LPG fuel system are to be provided.

4 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**, **Part GF of the Guidance of the Rules for the Survey and Construction of Steel Ships**

18.4.8 Gas Detection

1 Gas detection systems provided in accordance with the requirements of this Chapter are to activate the alarm at 30% *LFL* and shut down the master gas fuel valve required by **18.4.6** at not more than 60% *LFL* (See **13.6.17, Part N of the Rules**).

2 In addition to spaces required by **13.6.2**, **Part N of the Rules**, if necessary, gas detection systems are to be provided at the inlets of ventilation systems for accommodation spaces and machinery spaces.

18.5 LPG Fuel Plants and Related Storage Tanks

18.5.1 Provision of LPG Fuel

1 All equipment (heaters, compressors, vaporizers, filters, etc.) for conditioning the cargo and/or cargo boil off vapour for its use as fuel, and any related storage tanks, are to be located in the cargo area. If the equipment is in an enclosed space, the space is to be ventilated according to **12.1, Part N of the Rules** and be equipped with a fixed fire-extinguishing system, according to **11.5, Part N of the Rules**, and with a gas detection system according to **13.6, Part N of the Rules**, as applicable.

2 Ventilation systems serving hazardous spaces are to be arranged to be led to a safe location to avoid accumulation of LPG vapour in case of LPG/gas leakage.

3 The ventilation for enclosed or semi-enclosed spaces are to be so arranged taking into account of the form of spaces and properties of LPG that any accumulation may be prevented by the air inlet at upper part and air outlet at lower part of the spaces.

4 The closing devices of ventilation systems for hazardous spaces are to be capable of being closed from outside the spaces being ventilated. The means of closing are to be easily accessible as well as prominently and permanently marked and are to indicate whether the closing device is open or closed.

5 LPG fuel tanks, process pressure vessels and equipment located on open decks are to be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

Note: Arrangement of vent post, equipment, ventilation, opening and restricted area is to be taken into account the specific gravity of LPG/gas.

6 The number and arrangements of gas detectors are to be considered taking into account the size, layout and form where gas detectors are installed. Gas dispersal analysis or a physical smoke test is to be used to find the best arrangement when the Society and Administration deem it necessary.

7 At least two sets of portable gas detection equipment that meet the recognized standards acceptable to the Society are to be provided to measure the concentration of LPG/gas.

Note: The above wording “the recognized standards acceptable to the Society” means *IEC* 60079-29-1.

8 Any space containing equipment for LPG fuel preparation such as pumps and compressors is to be provided with fixed fire-extinguishing system specified **Chapter 25, Part R of the Rules**, unless the equipment is not regarded as an source of ignition.

9 Drip trays are to be fitted where LPG leakage may occur which can cause damage to the ship structure or where limitation of the area which is affected from a spill is necessary. Each tray is to be fitted with a means to detect LPG leakage and operate safety devices.

Note: Where leakage of high-pressure LPG fuel may occur, an appropriate means is to be arranged taking into account low temperature or other effects caused by high-pressure LPG expansion.

10 Electrical equipment and cables are not to be installed in hazardous areas unless it conforms to the requirements in **4.2.4, Part H of the Rules**.

Note: Hazardous area is to be decided by taking into account the properties of the LPG

11 LPG cargo tank and LPG fuel service tank are to be provided with appropriate means of atmospheric control such as gas freeing and purging so as to be safely emptied, taking into account the properties of the LPG.

12 Structure of venting system and arrangement of vent outlets required in **8.2.10**, **8.2.11** and **8.2.12**, **Part N of the Rules** are to be assessed by gas dispersal analysis or a physical test, however alternative arrangements may be accepted considered by the Society and Administration may be approved by the Society and Administration when they deem it equivalent.

13 For the LPG fuel supply system, the test to justify the compatibility with the expected operations may be required by the Society.

18.5.2 Remote Stops

1 All rotating equipment utilized for conditioning the fuel is to be arranged for manual remote stop from the engine-room. Additional remote stops are to be located in areas that are always easily accessible, typically cargo control room, navigation bridge and fire control station.

2 The fuel supply equipment is to be automatically stopped in the case of low suction pressure or fire detection. Unless expressly provided otherwise, the requirements of **18.3, Part N of the Rules** need not apply to gas fuel compressors or pumps when used to supply gas consumers.

18.5.3 Heating and Cooling Mediums

If the heating or cooling medium for the LPG fuel conditioning system is returned to spaces outside the cargo area, provisions are to be made to detect and alarm the presence of LPG/gas in the medium. Any vent outlet is to be in a safe position and fitted with an effective flame screen of an approved type.

18.5.4 Piping and Pressure Vessels

1 Piping or pressure vessels fitted in the LPG fuel supply system are to comply with **Chapter 5, Part N of the Rules**.

2 The piping and ducting which are likely to be exposed to low temperature caused by high-pressure LPG/gas leakage or vent discharge are to be designed taking into account the effect of vaporizing and expansion.

3 LPG fuel piping systems are to be of construction for avoiding accumulation of LPG/gas and be capable of proper gas-freeing and purging.

4 Double block and bleed valves, and closable non-return valve between these valves and LPG fuel piping are to be provided in the inert gas supply piping connecting with LPG fuel supply system for purging piping system to prevent back-flow of fuel vapour into the inert gas system

5 LPG systems are to be designed, constructed and insulated to prevent phase changes of LPG/gas in the supply system.

6 Where LPG fuel is intended to be used in the liquid state, the pressure in the fuel manifold is to be sufficiently maintained the fuel in the liquid state.

7 Where LPG fuel is intended to be used in the gaseous state, the ambient temperature is to be maintained lower than the dew point at the maximum expected pressure.

8 LPG fuel gas piping systems are to be fitted with means for safely removing the liquid in case the LPG fuel gas condenses in the piping.

18.6 Special Requirements for Main Boilers and Gas Combustion units

18.6.1 Arrangements

1 Each boiler and gas combustion unit is to have a separate exhaust uptake.

2 Each boiler and gas combustion unit 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.

3 Combustion chambers and uptakes of boilers and gas combustion units are to be designed to prevent any accumulation of LPG fuel.

18.6.2 Combustion Equipment

1 The burner systems are to be of dual type, suitable to burn either: oil fuel or LPG fuel alone, or oil and LPG fuel simultaneously.

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

3 An automatic system is to be fitted to change over from LPG fuel operation to oil fuel operation without interruption of the boiler firing, in the event of loss of LPG fuel supply.

4 LPG fuel nozzles and the burner control system are to be configured such that LPG 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.

18.6.3 Safety

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

2 On the pipe of each LPG fuelburner, a manually operated shut-off valve is to be fitted.

3 Provisions are to be made for automatically purging the LPG fuel supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

4 The automatic fuel changeover system required by **18.6.2-3** is to be monitored with alarms to ensure continuous availability.

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

6 Arrangements are to be made to enable the boilers and gas combustion units to be manually purged.

18.7 Special Requirements for LPG fired Internal Combustion Engines

Dual fuel engines are those that employ LPG fuel (with pilot oil) and oil fuel. Oil fuels may include distillate and residual fuels.

18.7.1 Arrangements

1 When gas is supplied in a mixture with air through a common manifold, flame arrestors are to be installed before each cylinder head.

2 Each engine is to have its own separate exhaust.

3 The exhausts are to be configured to prevent any accumulation of unburnt gaseous fuel.

4 Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, air inlet manifolds, scavenge spaces, exhaust system and crank cases are to be fitted with suitable pressure relief systems. Pressure relief systems are to lead to a safe location, away from personnel.

5 Each engine is to be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

6 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of LPG vapour accumulation in the crankcase is to be carried out and reflected in the safety concept of the engine.

7 The charge air system and intake manifold are to be designed to prevent presence and possible accumulation of LPG vapour.

8 The gas supply system for Otto cycle engines is to be designed to prevent condensation of LPG vapour.

18.7.2 Combustion Equipment

1 Prior to admission of LPG fuel, correct operation of the pilot oil injection system on each unit is to be verified.

2 For a spark ignition engine, if ignition has not been detected by the engine monitoring system within an engine specific time after opening of the LPG fuel supply valve, this is to be automatically shut off and the starting sequence terminated. It is to be ensured that any unburnt gas mixture is purged from the exhaust system.

3 For dual-fuel engines fitted with a pilot oil injection system, an automatic system is to be fitted to change over from LPG fuel operation to oil fuel operation with minimum fluctuation of the engine power.

4 In the case of unstable operation on engines with the arrangement in **-3** above when LPG fuel firing, the engine is automatically to change to oil fuel mode.

5 LPG fuel injection valves are to comply with the following:

(1) LPG fuel injection valves are to possess satisfactory operating characteristics and durability for the assumed service period.

(2) LPG fuel injection valves are to be provided with sealing systems to effectively prevent LPG fuel from leaking through spaces around valve spindles.

(3) LPG fuel injection valves are to be provided with effective cooling systems.

6 LPG fuel injection valve actuating systems are to comply with the following:

(1) LPG fuel injection valve actuating systems are to be reliably functional and operational.

(2) When operating LPG 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 LPG fuel injection valve actuating oil is required to be kept clean.

18.7.3 Safety

1 During stopping of the engine, the gas fuel is to be automatically shut off before the ignition source.

2 Arrangements are to be provided to ensure that there is no unburnt gas fuel in the exhaust gas system prior to ignition.

3 Crankcases, sumps, scavenge spaces and cooling system vents are to be provided with gas detection when the Society deems it necessary by the result of the evaluation required in **18.7.1-6** (See **13.6.17, Part N of the Rules**).

4 Provision is to be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase is to be in accordance with the requirements of **Chapter 10**, **Part N of the rules**.

5 A means is to be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the LPG fuel supply is to be shut down. Instrumentation fitted inside the exhaust system is to be in accordance with the requirements of **Chapter 10**, **Part N of the rules**.

6 Governors for LPG-fuel engines are to be capable of being operated both during LPG fuel and oil fuel or pilot oil combustion mode, and oil fuel only combustion mode.

7 Instrumentation systems for LPG-fuel engines are to be capable of monitoring LPG is in the appropriate phase required by the engine.

8 When LPG-fuel engines are operated by LPG fuel, exhaust gas temperatures at cylinder outlets are to be continuously monitored.

18.8 Operating Requirements

18.8.1 Application

The provisions in this chapter 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 ship master as well as all other persons responsible for the ship's operation.

18.8.2 Mechanical Ventilation of LPG Fuel Piping

Mechanical ventilation of pipes or ducts in which LPG fuel piping is installed is to always be in operation when there is LPG fuel in the piping.

18.8.3 Manual Purging of Boilers and Gas Combustion Units

Combustion chambers of boilers and gas combustion units are to be manually purged as needed in consideration of the provisions in **18.6.3**.

18.8.4 Fuel Handling Manuals

The content of the manuals is to include following **(1)** to **(2)**:

(1) Operation of ventilations and dampers at each gas hazardous area; and

(2) Temperature and pressure control, alarm and safety systems of fuel supply system.

18.8.5 Entry into Enclosed Spaces

1 Before entering any space which has the possibility of gas leakages, the persons in charge is to verify following:

(1) Ventilation is sufficient.

(2) LPG fuel gas detector and oxygen content measuring equipment operate correctly.

(3) Gas and oxygen concentrations are properly monitored and recorded.

18.8.6 Inerting and Purging of Fuel Systems

1 Procedure of gas freeing before dry-docks is to be approved by the Society and Administration beforehand when they deem it necessary.

Part C

Guidelines for Ships Using Ammonia as Fuel

CONTENTS

Chapter 1 PREAMBLE ... 1
1.1 Purpose ... 1
1.2 Structure ... 1
1.3 Other ... 1
Chapter 2 GENERAL ... 1
2.1 Application ... 1
2.2 Definitions ... 1
2.3 Submission of Plans and Documents ... 4
2.4 Class Notation ... 6
Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS ... 7
3.1 Goal ... 7
3.2 Functional Requirements ... 7
Chapter 4 GENERAL REQUIREMENTS ... 9
4.1 Goal ... 9
4.2 Risk Assessment ... 9
4.3 Limiting the Aftereffects of Explosions ... 9
4.4 Limiting the Effects of Toxic Atmosphere Formation ... 9
Chapter 5 SHIP DESIGN AND ARRANGEMENT ... 11
5.1 Goal ... 11
5.2 Functional Requirements ... 11
5.3 General Requirements ... 11
5.4 Concepts for Gas Safe Machinery Spaces ... 14
5.5 Location and Protection of Fuel Piping ... 14
5.6 Fuel Preparation Room Design ... 14
5.7 Bilge Systems ... 15
5.8 Drip Trays ... 15
5.9 Arrangement of Entrances and Other Openings in Enclosed Spaces ... 16
5.10 Airlocks ... 17
Chapter 6 FUEL CONTAINMENT SYSTEM ... 19
6.1 Goal ... 19
6.2 Functional Requirements ... 19
6.3 General Requirements ... 19
6.4 Fuel Containment ... 20
6.5 Portable Liquefied Gas Fuel Tanks ... 48
6.6 Pressure Relief Systems ... 49
6.7 Loading Limit for Liquefied Gas Fuel Tanks ... 54
6.8 Maintaining Fuel Storage Conditions ... 55
6.9 Atmospheric Control in Fuel Containment Systems ... 56
6.10 Atmosphere Control Within Fuel Storage Hold Spaces (Fuel Containment Systems Other Than Type *C* Independent Tanks) 56
6.11 Environmental Control of Spaces Surrounding Type *C* Independent Tanks ... 57
6.12 Inerting ... 57
6.13 Inert Gas Production and Storage on Board ... 57

Chapter 7 MATERIAL AND GENERAL PIPE DESIGN 59
7.1 Goal 59
7.2 Functional Requirements 59
7.3 General Pipe Design 59
7.4 Regulations for Materials 62
Chapter 8 BUNKERING 74
8.1 Goal 74
8.2 Functional Requirements 74
8.3 Bunkering Stations 74
8.4 Manifolds 75
8.5 Bunkering Systems 75
Chapter 9 FUEL SUPPLY TO CONSUMERS 77
9.1 Goal 77
9.2 Functional Requirements 77
9.3 Fuel Supply Redundancy 77
9.4 Safety Functions of Gas Supply Systems 78
9.5 Fuel Temperature and Pressure Control 79
9.6 Fuel Distribution Outside of Machinery Spaces 79
9.7 Fuel Supply to Fuel Consumers in Gas-safe Machinery Spaces 80
9.8 The Design of Ventilated Ducts and Outer Pipes Against Inner Pipe Gas Leakage 80
9.9 Compressors and Pumps 81
Chapter 10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS 83
10.1 Goal 83
10.2 Functional Requirements 83
10.3 Piston-type Internal Combustion Engines 83
10.4 Main and Auxiliary Boilers 85
Chapter 11 FIRE SAFETY 87
11.1 Goal 87
11.2 Functional Requirements 87
11.3 General Requirements 87
11.4 Fire Protection 87
11.5 Fire Mains 87
11.6 Water Spray Systems 88
11.7 Fire-Extinguishing System in Fuel Preparation rooms 88
11.8 Dry Chemical Powder Fire-extinguishing Systems 88
Chapter 12A EXPLOSION PREVENTION 90
12A.1 Goal 90
12A.2 Functional Requirements 90
12A.3 General 90
12A.4 Hazardous Areas 90
12A.5 Hazardous Area Zones 91
Chapter 12B TOXIC HAZARDOUS AREAS 92
12B.1 Purpose 92
12B.2 Functional requirements 92
12B.3 General Requirements 92

12B.4 Classification of Toxic Hazardous Areas 92
Chapter 13 VENTILATION 95
13.1 Goal 95
13.2 Functional requirements 95
13.3 General Requirements 95
13.4 Tank Connection Spaces 97
13.5 Machinery Spaces 98
13.6 Fuel Preparation Rooms 98
13.7 Bunkering Stations 98
13.8 Ducts and Double Pipes 99
13.9 Other 99
13.10 Increased Ventilation Requirements 99
Chapter 14A SAFETY REQUIREMENTS FOR AMMONIA FLAMMABILITY (ELECTRICAL INSTALLATIONS) . 102
14A.1 Goal 102
14A.2 Functional Requirements 102
14A.3 General Requirements 102
Chapter 14B SAFETY REQUIREMENTS FOR AMMONIA TOXICITY 104
14B.1 Purpose 104
14B.2 Functional requirements 104
14B.3 General Requirements 104
Chapter 15 CONTROL, MONITORING AND SAFETY SYSTEMS 109
15.1 Goal 109
15.2 Functional Requirements 109
15.3 General 109
15.4 Bunkering and Liquefied Gas Fuel Tank Monitoring 110
15.5 Bunkering Control 111
15.6 Gas Compressor Monitoring 112
15.7 Gas Engine Monitoring 112
15.8 Gas Detection 112
15.9 Fire Detection 113
15.10 Ventilation 114
15.11 Fuel Supply System Safety Functions 114
Chapter 16 MANUFACTURE, WORKMANSHIP AND TESTING 117
16.1 General 117
16.2 General Test Regulations and Specifications 117
16.3 Welding of Metallic Materials and Non-destructive Testing for Fuel Containment Systems 120
16.4 Other Regulations for Construction in Metallic Materials 123
16.5 Testing for Tanks 123
16.6 Welding, Post-weld Heat Treatment and Non-destructive Testing 126
16.7 Testing for Pipings 126
Chapter 17 OPERATING REQUIREMENTS 129
17.1 Goal 129
17.2 Functional Requirements 129
17.3 Fuel Handling Manuals and Notices 129
17.4 Maintenance and Repair Procedures 130

17.5 Operating Requirements 130
Chapter 18 USE OF CARGO AS FUEL 134
18.1 General 134
18.2 Use of Cargo Vapour as Fuel 135
18.3 Spaces Containing Fuel Consumers 135
18.4 Fuel Supply 136
18.5 Fuel Conditioning Systems and Associated Storage Tanks 139
18.6 Special Requirements for Main Boilers and Auxiliary Boilers 140
18.7 Special Requirements for Gas-fired Internal Combustion Engines 141
18.8 Flammable Hazardous Areas Other Than Cargo Areas 142
18.9 Toxic Hazardous Areas Other Than Cargo Areas 143
18.10 Operating Requirements 144
18.11 Operation Manuals 144

Chapter 1 PREAMBLE

1.1 Purpose

The *Guidelines for Ships Using Ammonia as Fuel* (hereinafter referred to as “the Guidelines”) makes reference to requirements specified in SOLAS, the IGC Code and the IGF Code with a view to minimizing the risks to ships, seafarers and the environment in consideration of the particular characteristics of ammonia as well as the standards for the equipment (including associated control and monitoring systems) installed on board ships using ammonia as fuel, which have been independently established by the Society up until now. The Guidelines is intended to be helpful with respect to the implementation of alternative designs as well as the submission of requests for approval to Flag State Administrations related to the use of ammonia as fuel. Although this version of the Guidelines was primarily developed based on currently available information, the Society intends to regularly review and update it as deemed necessary so as to fully incorporate the knowledge obtained from future operational data and research and development results to ensure that the information contained therein does not become outdated or otherwise inaccurate.

1.2 Structure

The Guidelines consists of two parts: **Part C-1** and **Part C-2**.

1.2.1 Part C-1

In **Part C-1**, the Society has independently established guidelines for the equipment (including associated control and monitoring ships) installed on board ships which use ammonia as fuel and not subject to **Part N of Rules for the Survey and Construction of Steel Ships** (hereinafter referred to as “**the Rules**”).

1.2.2 Part C-1

Part C-2 is applicable to liquefied gas bulk carriers subject to **Part N of the Rules** which use ammonia as fuel. In such cases, the alternative designs referred to in **16.9, Part N of the Rules** are required to be implemented in accordance with **1.1.2, Part N of the Rules**; moreover, Flag State Administration approval is further needed on the condition that the same degree of safety as is required for using methane as fuel is ensured. **Part C-2**, therefore, includes independently established guidelines for the equipment (including their associated control and monitoring systems) installed on such ships for the purpose of using ammonia as fuel.

1.3 Other

The “Note” sections found in the Guidelines contain information about items for which further clarification is deemed necessary.

Part C-1 Guidelines for the Safety of Ships Using Ammonia as Fuel

Chapter 2 GENERAL

2.1 Application

1 This part applies to ships using low-flashpoint fuels, except for those ships specified in the following (1) or (2):

(1) Gas carriers using their cargoes as fuel and complying with the requirements of **Part N of the Rules**; or

(2) Gas carriers using other low-flashpoint gaseous fuels, provided that the fuel storage and distribution system designs and arrangements for such gaseous fuels comply with the requirements of **Part N of the Rules**.

2 Constructions, equipment, etc. which do not fall under the requirements of this part may be accepted, provided that they are considered equivalent to those required to comply with this part.

2.2 Definitions

Unless expressly provided otherwise, terms used in this part are defined as follows.

1 *Ammonia* means an inorganic compound represented by the chemical formula NH3; moreover, it means either gaseous or liquid, or a combination of both when referred to in the Guidelines.

2 *Ammonia gas* means gaseous ammonia.

3 *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.

4 *Breadth (B')* means the greatest moulded breadth of the ship at or below the deepest subdivision draught (i.e. the summer load line draught). Refer to **4.1.2(3), Part C of the Rules** for more details.

5 *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.

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

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

8 *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.

9 *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.

10 *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.

11 *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.

12 *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.

13 *ESD* means emergency shutdown.

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

15 *Fuel containment system* is the arrangement for the storage of fuel including tank connections. It includes (in cases where fitted) primary and secondary barriers, associated insulation and any intervening spaces as well as adjacent structures (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 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.

(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, vapourizers, heat exchangers or pressure vessels for fuel preparation purposes.

18 *Fuel consumer* means any unit within the ship using ammonia as a fuel.

19 *Fuel only engine* means an engine capable of operating only on ammonia, and not able to changeover to operation on any other type of fuel.

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

21 *Hazardous area* means the following **(1)** and **(2)** unless specified otherwise.

(1) *Hazardous areas* related to flammability specified in **1.1.5, Part H of the Rules** which are listed in **Chapter 12A**.

(2) *Hazardous areas* related to toxicity specified in **Chapter 12B**.

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

23 *Ammonia gas Expulsion System* means a device that quickly removes ammonia gas from the compartment.

24 *Length (L_f)* is the length as defined in **2.1.3, Part A of the Rules**.

25 *Liquefied Gas* means liquid ammonia.

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

27 *Low-flashpoint fuel* means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under **4.2.1(1), Part R of the Rules**.

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

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

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

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

32 *Non-hazardous area* means the following **(1)** and **(2)**.

(1) A place where there is no risk of an explosive atmosphere requiring special attention to the structure, installation and use of the equipment.

(2) A place where there is no risk of the generation of ammonia gas that is hazardous to human health.

33 *Open deck* means a deck 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.

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

35 *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).

36 *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 structure to an unsafe level.

37 *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 structures such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.

38 *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 or ammonia concentration atmosphere that affects the human body could be formed.

39 *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 of the Rules**.

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

41 *Fuel* means ammonia, either in its liquefied or gaseous state.

42 *Fuel pipes* means a bunkering pipes and fuel supply pipes. However, in applying **Chapter 9**, bunkering pipes are not included.

43 *Fuel tank* means the tank that stores the fuel specified in **-41** above.

44 *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 International Maritime Organization (hereinafter referred to as the "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 regulations of Article VIII of SOLAS concerning the amendment procedures applicable to annexes other than Chapter I thereof.

2.3 Submission of Plans and Documents

In addition to plans and documents specified in **2.1.2 and 2.1.3**, **Part B of the Rules**, the following drawings and materials are to be submitted.

1 Manufacturing specifications for fuel tanks, thermal insulations and secondary barriers (including welding procedures, inspection and testing procedures for welds and fuel tanks, installation procedures of thermal insulation materials and secondary barriers, and working standards)

2 Arrangements and construction of fuel tanks

3 System drawings and arrangements of fuel tank accessories (including details of the internal fittings)

4 Arrangements and construction of fuel tank supports

5 Construction of fuel tank deck portions through which fuel tanks penetrate, and their sealing arrangements

6 Arrangements and construction of secondary barriers

7 Specifications or standards for materials used for fuel tanks, thermal insulations, secondary barriers and fuel tank supports

8 Layout and detailed installation of thermal insulations

9 Arrangements and construction of ammonia gas expulsion systems (refer to **13.10**)

10 System drawings and arrangements of ammonia gas expulsion systems (including details of the internal fittings)

11 Construction of ammonia gas expulsion system deck portions through which ammonia gas expulsion systems penetrate, and their associated sealing arrangements

12 Specifications or standards for materials used for ammonia gas expulsion systems

13 Piping diagrams for ammonia gas expulsion systems

14 Manufacturing specifications for fuel piping systems (including welding procedures, testing and inspection procedures for fuel piping, installation procedures of double wall piping, ducts and thermal insulation materials and secondary barriers, and working standards)

15 Piping diagrams (including materials, sizes, kinds, design pressures, design temperatures, etc. of pipes, valves, etc.) of fuel piping, fuel gauging systems and fuel vent piping

16 Bilge systems in fuel storage hold spaces or interbarrier spaces, fuel preparation rooms, tank connection spaces and bunkering stations

17 Specifications, piping diagrams and arrangements of fire detection and ammonia gas detection systems

18 Piping diagrams of inert gas lines and details (including information on design specifications, construction, materials, etc.) of pressure adjusting devices in cases where fuel storage hold spaces or interbarrier spaces may be inerted

19 Details of pressure relief systems for fuel storage hold spaces, interbarrier spaces and tank connection spaces as well as details of drainage arrangements for leaked fuel

20 Assembly cross section of various pressure vessels, details of nozzles, system drawings of fittings and details of fittings

21 Electric wiring plans for hazardous areas and tables for electrical equipment in hazardous areas

22 Arrangements of electrical bonding for fuel tanks, piping systems, machinery, equipment, etc.

23 Plans showing flammable hazardous areas

24 Plans showing toxic hazardous areas

25 Arrangements of equipment installed in fuel preparation rooms, tank connection spaces, bunkering stations and bunkering control stations

26 Inspection/survey plans for fuel containment systems

27 Arrangements of access to hazardous areas, fuel preparation rooms, tank connection spaces, and inerted spaces and guides for said access thereto (including airlocks)

28 Diagrams of control systems (including monitoring, safety and alarm systems) for bunkering systems, fuel tanks, fuel supply systems and fuel consumers and lists of the setting values

29 Plans and documents of the low-flashpoint fuel equipment and fittings specified in **1.2, Annex 1, Part GF of the Guidance**

30 Plans and documents for the gas-fuelled boilers specified in **1.3, Annex 2, Part GF of the Guidance**

31 Plans and documents for the gas combustion units (GCUs) specified in **1.3, Annex 2A, Part GF of the Guidance**

32 Plans and documents for the gas-fuelled engines specified in **1.3, Annex 3 and 1.3, Annex 4, Part GF of the Guidance**

33 Arrangements and construction of ventilation systems (including materials, ventilation capacity, etc.)

34 Arrangements of ventilation inlets and exhaust outlets

35 Ventilation duct diagrams (including design pressures, materials, and arrangements and construction of fittings)

36 Details of bunkering manifold connections

37 Drawings showing distance between fuel tanks and shell plating at each section

38 Arrangements, capacity calculation sheets and details of drip trays (including materials, thermal protection for the hull structure and drainage arrangements)

39 Access routes and means of access to protected spaces within hold spaces

40 Arrangements of airlock doors, airlock ventilation capacity calculation sheets and details of airlock alarm systems

41 Arrangements of the equipment specified in **14B.3.6**

42 Other plans and documents not specified in **-1** through **-41** above which are deemed necessary by the Society

2.4 Class Notation

For ships designed and surveyed in accordance with the requirements of the Guidelines and which are found by the Society to comply said requirements, the class notation “Character: A-fuel, Description: Ammonia fuel” is to be affixed to the classification characters of the ship.

Chapter 3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of this chapter is to provide for the 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 other purpose machinery using ammonia as fuel.

3.2 Functional Requirements

3.2.1 Safety, Reliability and Dependability of 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 arrangements (such as ventilation, detection and safety) and system design,. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

3.2.3 Fuel Installation Design

The design philosophy is to ensure that risk reducing measures and safety actions for the 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 ship safety as well as the safety of ship personnel 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 Ammonia

Unintended accumulation of explosive, flammable and 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 Ignition Sources in Flammable Hazardous Areas

Ignition sources in flammable hazardous areas are to be minimized to reduce the probability of explosions in enclosed and semi-enclosed spaces.

3.2.9 Gas Fuel Supply, Storage and Bunkering Arrangements

Arrangements are to be provided to ensure a safe and suitable fuel supply as well as to ensure that the storage and bunkering of the fuel in its required state can be carried out 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 systems and machinery spaces containing sources that might release ammonia into the space are to be arranged and located so that a fire explosion or toxicity in either such systems or spaces will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

3.2.13 Safe and Reliable 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, and design standards as well as 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 to not lead to an unsafe or unreliable situation.

3.2.19 Toxicity Related Safety Measures

Measures to minimize the health hazards associated with the toxicity of ammonia are to be provided.

Chapter 4 GENERAL REQUIREMENTS

4.1 Goal

The goal of this chapter is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effects on ships, their personnel, or the environment.

4.2 Risk Assessment

4.2.1 General Requirements

A risk assessment is to be conducted to ensure that risks arising from the use of fuels affecting ship personnel, the environment, and ship structural strength or integrity 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 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, toxicity 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 Limiting the Aftereffects of Explosions

Fires or explosions in spaces containing potential fuel release sources and ignition sources are to not lead to any of the following:

(1) damaging to or disrupting the proper functioning of equipment or systems located in spaces other than that in which the incident occurs;

(2) damaging the ship in such a way that flooding of water below the main deck or any progressive flooding occurs;

(3) damaging work or accommodation spaces in such a way that creates health hazards for ship personnel normally present in such spaces under normal operating conditions;

(4) disrupting the proper functioning of control stations and switchboard rooms necessary for power distribution;

(5) disrupting the proper functioning of firefighting equipment located outside explosion-damaged or fire-damaged spaces;

(6) affecting other areas of the ship in such a way that chain reactions involving cargo and bunker oil may arise; or

(7) preventing ship personnel from accessing life-saving appliances or impeding their escape routes.

4.4 Limiting the Effects of Toxic Atmosphere Formation

The generation of a toxic atmosphere in any space containing potential fuel release sources and ignition sources are to not lead to any of the following:

(1) damaging or disrupting the proper functioning of equipment or systems located in spaces other than that in which the incident occurs;
(2) health hazards for ship personnel normally present in work or accommodation spaces under normal operating conditions;
(3) disrupting the proper firefighting activities;
(4) affecting other areas of the ship in such a way that chain reactions involving cargo and bunker oil may arise; or
(5) preventing ship personnel from accessing life-saving appliances or impeding their escape routes.

Chapter 5 SHIP DESIGN AND ARRANGEMENT

5.1 Goal

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

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**, **3.2.7**, **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 Fuel tanks are to be located in such a way that the probability for the tanks 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 release sources are to be so located and arranged that leaked ammonia is released into the atmosphere from safe locations.

3 The access or other openings to spaces containing fuel release sources are to be so arranged that ammonia gas or liquid cannot escape into spaces that are not designed for its presence.

4 Fuel piping and related fuel supply system are to be protected against mechanical damage.

5 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 space where fuel containing machinery and equipment are installed is to be designed to minimize the probability of the following hazards.

(1) Fire and explosion.

(2) Exposure of ship personnel to leaked ammonia.

5.3 General Requirements

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 requiring secondary barriers are to be located to ensure sufficient natural ventilation so as to prevent the accumulation of leaked gas in cases where the tanks are to be located on open decks.

5.3.3 Fuel Tank Locations

Fuel tanks are to be protected from external damage caused by collision or grounding in the following ways.

(1) Fuel tanks are to be located at a minimum distance of *B'*/5 or 11.5 *m* (whichever is less) as measured inboard from the ship sides at right angles to the centreline at the height of the summer load line draught.

(2) Boundaries of fuel tanks 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, protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks, such distance is to be measured to the bulkheads surrounding the tank insulation.

(4) In no cases are the boundaries of fuel tanks to be located any closer to shell plating or aft terminals of ships than as follows.

i) 0.8 *m* (for V_c below or equal 1,000 m^3)

ii) $0.75 + V_c \times 0.2/4{,}000$ (*m*) (for 1,000 $m^3 < V_c <$ 5,000 m^3)

iii) $0.8 + V_c/25{,}000$ (*m*) (for 5,000 $m^3 \leq V_c <$ 30,000 m^3)

iv) 2.0 *m* (for $V_c \geq$ 30,000 m^3)

where

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

(5) The lowermost boundaries of fuel tanks are to be located above the minimum distance of *B'*/15 or 2.0 *m* (whichever is less) as measured from the moulded line of the bottom shell plating at the centreline.

(6) For multi-hull ships, the value of *B'* may be specially considered.

(7) Fuel tanks are to be located abaft of collision bulkheads.

(8) For ships with hull structures providing higher collision 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} is to be calculated as described in the following and is to be less than 0.04. The value f_{CN} accounts for collision damage that may occur within a zone limited only by the longitudinal projected boundaries of the fuel tank 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 value f_{CN} is to be calculated using the following formula

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

where

f_l: Calculated by using the formulae for factor p specified in **4.2.2-2, Part C of the Rules**. The value of $x1$ corresponds to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of $x2$ corresponds 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 formula to be used is given below. 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.

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

f_v: Calculated by following formulae

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

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

where

H: the distance from baseline (m) to the lowermost boundary of the fuel tank

d: the deepest draught (summer load line draught)

(3) The boundaries of fuel tanks 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, protective distance is to be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks, such distance is to be measured to the bulkheads surrounding the tank insulation.

(5) In no cases are the boundaries of fuel tanks to be located any closer to shell plating or aft terminals of ships than as follows.

i) 0.8 m (for V_c below or equal 1,000 m^3)

ii) $0.75 + Vc \times 0.2/4{,}000$ (m) (for 1,000 $m^3 < V_c <$ 5,000 m^3)

iii) $0.8 + Vc/25{,}000$ (m) (for 5,000$m^3 \leq V_c <$ 30,000 m^3)

iv) 2.0 m (for $V_c \geq$ 30,000 m^3)

where

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

(6) In cases where more than one non-overlapping fuel tank is located in the longitudinal direction, f_{CN} is to be separately calculated in accordance with **(2)** for each fuel tank. The value used for the entire fuel tank arrangement is to be the sum of the f_{CN} values obtained for each separate tank.

(7) In cases where fuel tank arrangements are asymmetrical about the centreline of the ship, f_{CN} is to be calculated for both the starboard and port side, and the average value is to be used for the assessment. The minimum distance specified in **(5)** is to be met for both sides.

(8) For ships with a hull structure providing higher collision 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 fuel containment systems requiring complete or partial secondary barriers, the following **(1)** and **(2)** are to be satisfied:

(1) fuel storage hold spaces are to be segregated from the sea by double bottoms; and

(2) fuel storage hold spaces are to be segregated from the sea by longitudinal bulkheads forming side spaces.

5.4 Concepts for Gas Safe Machinery Spaces

5.4.1 General

Machinery spaces with gas-fuelled machinery are to be designed as gas safe machinery spaces. Gas safe machinery spaces are to be such that the spaces are considered gas safe under all normal and abnormal conditions (i.e. inherently gas safe).

5.4.2 Prevention of the Release of Gas

In gas safe machinery spaces, a single failure is to not lead to the release of fuel gas into the machinery space.

5.4.3 Fuel Piping

Fuel piping within machinery space boundaries are to be enclosed in gas and liquid tight enclosures in accordance with **9.7**.

5.5 Location and Protection of Fuel Piping

5.5.1 Distance from Ship Sides

Fuel piping and related fuel supply system are to not be located less than 800 *mm* from the ship sides.

5.5.2 Location of Fuel Piping

1 Fuel piping is to not be led through accommodation spaces, service spaces, electrical equipment rooms or control stations. It is not acceptable even if these piping are enclosed by secondary enclosures.

Note: It is acceptable for fuel piping to be led through accommodation spaces, service spaces, electrical equipment rooms or control stations in cases where its secondary enclosure is surrounded by another gastight enclosure.

2 Fuel piping is to be designed to enable drainage to be led to suitable tanks under list and trim conditions during voyage.

3 Splash shields are to be installed in fuel piping at locations where liquid fuel may flow out in a single failure.

5.5.3 Protection of Fuel Piping

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

5.6 Fuel Preparation Room Design

1 Fuel preparation rooms are to be gastight towards adjacent spaces, and they are to not be adjacent to accommodation spaces, service spaces, electrical equipment rooms or control stations when only separated by a single bulkhead or deck. The term “adjacent” means facial contact, linear contact, and point contact.

2 Fuel preparation rooms are to be designed to minimize the accumulation of gases or formation of gas pockets.

3 Materials used for the boundaries of fuel preparation rooms are to have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space (i.e. bulkheads and decks) are provided with suitable thermal protection. In addition, fuel preparation rooms are to be arranged to prevent surrounding hull structures from being exposed to unacceptable cooling.

4 Fuel preparation rooms are to be designed to withstand the maximum pressures that build up during a probable maximum leakage scenario. Alternatively, pressure relief venting to a safe location may be provided.

5.7 Bilge Systems

5.7.1 Segregation of Bilge Systems

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

5.7.2 Drainage Systems

Where fuel is carried in fuel containment systems requiring secondary barriers, suitable drainage arrangements for dealing with any leakage into holds or insulation spaces through the adjacent ship structure are to be provided. Bilge systems are to not lead to pumps in spaces where fuel cannot be present. In addition, means for detecting leakage are to be provided.

5.7.3 Drainage Systems for Liquid Fuels

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

5.8 Drip Trays

5.8.1 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 affected from a spill is necessary.

Note: Drip trays which is installed in high-pressure piping are to be designed considering the effect of expansion and latent heat of ammonia.

5.8.2 Materials

Drip trays are to be made of suitable material.

5.8.3 Thermic Protection

Drip trays are to be thermally insulated from the ship structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling in the case of liquid fuel leakage.

5.8.4 Drain Valves

Drip trays installed in areas where rainwater may be present are to be fitted with drain valves to enable drainage over the ship sides.

5.8.5 Risk Assessment

Drip trays are to have a sufficient capacity to ensure that the maximum spillage amount according to the risk assessment can be handled.

Note: When calculating the capacity of the drip tray, the effects of evaporation may be considered. The surrounding temperature is to be set as the most severe condition.

5.9 Arrangement of Entrances and Other Openings in Enclosed Spaces

5.9.1 Access to Hazardous Areas

Direct access is to not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with **5.10** is to be provided.

5.9.2 Access to Fuel Preparation Rooms

Fuel preparation rooms are, as far as practicable, to be independently and directly accessible from open decks. Where separate access from decks is not practicable, airlocks which comply with **5.12** are to be provided.

5.9.3 Access to Tank Connection Spaces

Tank connections space are, as far as practicable, to be independently and directly accessible from open decks. Where separate access from decks is not practicable, airlocks which comply with **5.12** or bolted hatches are to be provided.

5.9.4 Access to Inerted Spaces

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

5.9.5 Access to Fuel Tank Hold Spaces and Other Enclosed Hazardous Spaces

Arrangements for hold spaces, void spaces, fuel tanks and other spaces classified as hazardous areas, are to be such as to allow entry and inspection of any such space by ship personnel wearing protective clothing and breathing apparatus as well as to allow for the evacuation of injured or unconscious ship personnel. Such arrangements are to comply with the following.

(1) Access is to be provided as follows.

(a) Access to fuel tanks

Access is, as far as practicable, to be directly from open decks.

(b) Access through horizontal openings, hatches or manholes

The size is to be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 *mm* × 600 *mm*.

(c) Access through vertical openings or manholes providing passage through the length and breadth of the space The minimum clear opening is to be not less than 600 *mm* × 800 *mm* at a height of not more than 600 *mm* from the bottom plating unless gratings or other footholds are provided.

(d) Circular access openings to type *C* tanks are to have a diameter of not less than 600 *mm*.

(2) The sizes referred to in **(1)(b)** and **(c)** may be decreased, if **5.9.5** can be met to the satisfaction of the Society.

(3) Where fuel is carried in containment systems requiring secondary barriers, **(1)(b)** and **(c)** do not apply to spaces separated from hold spaces by a single gastight steel boundary. Such spaces are to be provided only with direct or indirect access from open decks, excluding any enclosed non-hazardous areas.

5.10 Airlocks

5.10.1 Structure

Airlocks are spaces 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 **Chapters 18, 19 and 20, Part C of the Rules**, door sills are to not be less than 300 *mm* in height, and doors are to be self-closing without any holding back arrangements.

5.10.2 Mechanical Ventilations

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

5.10.3 Design

Airlocks are to be designed in a way that no gas can be released to safe spaces in the case of the most critical event in gas dangerous spaces separated by airlocks. Such events are to be evaluated by risk assessments according to **4.2**.

5.10.4 Shape

Airlocks are to have a simple geometrical form. They are to provide free and easy passage and are to have a deck area not less than 1.5 m^2. Airlocks are to not be used for other purposes; for example, they are to not be used as store rooms.

5.10.5 Audible and Visual Alarms

Audible and visual alarm systems to give warnings on both sides of airlocks are to be provided to indicate if more than one door is moved from the closed position.

5.10.6 Restriction of Access

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

5.10.7 Essential Equipment for Safety

Essential equipment required for safety is to not 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

6.1.1 General

The goal of this chapter is to provide that gas storage is adequate so as to minimize the risk to ship personnel, ships and the environment to levels that are equivalent to those of conventional oil-fuelled ships.

6.2 Functional Requirements

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 3.2.18**. In particular the following apply:

6.2.2 Additional Requirements

1 Fuel tanks are to be so designed that leaks from tanks or their connections do not endanger ships, their personnel, or the environment. Potential dangers to be avoided include the following:

(1) exposure of ship materials to temperatures below acceptable limits;

(2) flammable fuels spreading to locations with ignition sources;

(3) health hazards of toxic fuel and inert gas;

(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 system is to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power.

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

6.3.1 General

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

2 Tank connection spaces and fuel storage hold spaces where fuel tanks (except type *C* independent tanks) are located are to be gastight towards adjacent spaces. These spaces are not be adjacent to accommodation spaces, service spaces, electrical equipment room, control stations by a single bulkhead or deck. Adjacent includes liner contact and point contact.

3 All tank connections, fittings, flanges and tank valves must be enclosed in gastight tank connection spaces. The space is to be able to safely contain leakage from the tank in case of leakage from the tank connections.

Note: Tank connection spaces are also required for the tank connections on open decks.

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

5 Piping between the tank and the first valve which release liquid in case of pipe failure are to have safety equivalent to a type *C* tank, with dynamic stress not exceeding the values given in **6.4.15-3(1)(b)**.

6 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.

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

8 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.

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

10 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. For further information, see the detailed requirements specified in **6.9**.

6.4 Fuel Containment

6.4.1 General

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

2 The design life of a fixed fuel containment system is to not 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 Fuel containment systems are 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 fuel containment systems used exclusively for restricted navigation. More demanding environmental conditions may be required for 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 Fuel containment systems are to be designed with suitable safety margins for the following:

(1) be capable of withstanding, in the intact condition, the environmental conditions anticipated for the 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) be appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, aging and construction tolerances.

6 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 fuel containment system are given in **6.4.15**. There are three main categories of design conditions:

(1) Ultimate Design Conditions: The 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 fuel containment system structure and its structural components is not to fail under accumulated cyclic loading.

(3) Accidental Design Conditions: The fuel containment system is to meet each of the following accident design conditions (accidental or abnormal events), addressed in this part:

(a) Collision: The 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 fuel containment system is to sustain without rupture the rise in internal pressure specified in **6.6.3-1** under the fire scenarios envisaged therein.

(c) Flooded compartment causing buoyancy in tanks: 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 implemented to ensure that scantlings required meet the structural strength requirements and are maintained throughout the design life. Such measures may include but are not limited to material selection, coatings, corrosion additions, cathodic protection and inerting.

8 An inspection or survey plan for the fuel containment system is to be developed and approved by the Society. The inspection or survey plan is to identify aspects to be examined or validated during surveys throughout the fuel containment system's life and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting 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 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. 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 Fuel Containment Safety Principles

1 Fuel 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 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 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 Type

The secondary barriers in relation to the tank type defined in **6.4.15** are to be provided in accordance with the following table.

Table 6.1 Tank Type and Secondary Barrier

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

6.4.4 Secondary Barrier Design

The design of secondary barriers (including spray shield if fitted) is to be as follows.

(1) It is to be 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 to be 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 the following as a minimum:

(a) details on the size of defect acceptable and the location within the secondary barrier before 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) It is to be capable of fulfilling its functional requirements at a static angle of heel of 30 *degrees*.

6.4.5 Partial Secondary Barriers and Primary Barrier Small Leak Protection Systems

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, means to deflect any liquefied gas fuel (such as a spray shield) 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 tank geometry does not provide 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 Structures and Equipment

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 **6.8**.

6.4.9 Design Loads

1 General

(1) This **6.4.9** 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, and
- wind impact, wave impacts and green sea effects for tanks installed on open decks.

(a) Internal pressure

i) In all cases, including the following **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 as follows.

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 is to be the greater of *P*eq1 and *P*eq2 calculated as follows.

$$P_{eq1} = P_0 + (P_{gd})\max(MPa)$$

$$P_{eq2} = P_h + (P_{gd}site)\max(MPa)$$

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 is to be calculated as follows.

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

where

a_β: dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads in an arbitrary direction β (see **Fig. GF6.1**). For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, is to be used.

z_β: largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see **Fig. GF6.2**). Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining z_β unless the total volume of tank domes V_d does not exceed the following value.

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

where

V_t : tank volume without any domes

FL: filling limit according to **6.7**

ρ : maximum liquefied gas fuel density (*kg/m*3) at the design temperature

The direction that gives the maximum value $(P_{gd})max$ or $(P_{gd}site)max$ 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

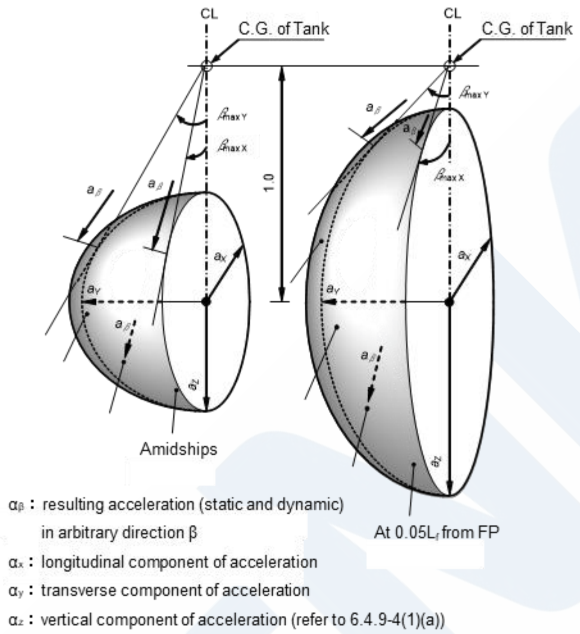
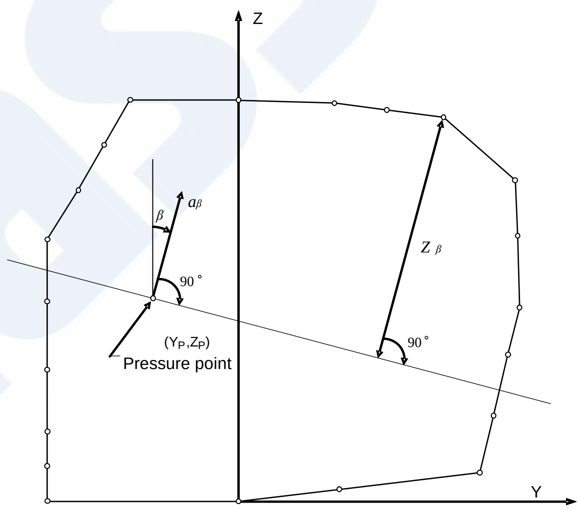


Fig. GF6.2 Determination of Internal Pressure Heads



(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

i) Transient thermally induced loads during cooling down periods are to be considered for tanks intended for liquefied gas fuel temperatures below −55°C.

ii) Stationary thermally induced loads are to be considered for a fuel containment system for which the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see **6.8.2**).

(d) Vibration

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

(e) Interaction loads

The static component of loads resulting from interaction between the 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 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 *degrees* are to be considered.

(i) Other loads

Any other loads not specifically addressed that could have an effect on the fuel containment system are to be taken into account.

4 Environmental loads

(1) Environmental loads are defined as those loads on the 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 motions are 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 of the Rules** for the 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 the fuel containment system and the hull structure, including loads from associated structures and equipment.

(c) Sloshing loads

The sloshing loads acting on the 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 the fuel containment system and its supporting arrangements under abnormal and unplanned conditions.

(a) Collision loads

The collision load is to be determined based on the fuel containment system under the fully loaded condition with an inertial force corresponding to "*a*" in **Table 6.2** in forward direction and "*a* /2" in the aft direction, where "*g*" is gravitational acceleration.

Table 6.2 Design Acceleration for Collision Loads

Ship length (Lf)	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 gastightness.

(2) The structural integrity of the fuel containment system can be demonstrated by compliance with **6.4.15**, as appropriate for the fuel containment system type.

(3) For other 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 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 the following.

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

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

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

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

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

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

where $\sigma_{x\cdot st}$, $\sigma_{y\cdot st}$, $\sigma_{z\cdot st}$, $\tau_{xy\cdot st}$, $\tau_{xz\cdot st}$ and $\tau_{yz\cdot st}$ are static stresses and $\sigma_{x\cdot dyn}$, $\sigma_{y\cdot dyn}$, $\sigma_{z\cdot dyn}$, $\tau_{xy\cdot dyn}$, $\tau_{xz\cdot dyn}$ and $\tau_{yz\cdot dyn}$ 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 requirements of this chapter.

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 108 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 are unavoidable (i.e. where the weld metal has lower tensile strength than the parent metal as in the case of 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 the fuel containment system.

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 σ_c (von Mises, Huber) is to be determined by the following.

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

where

σ_x : total normal stress in *X*-direction

σ_y : total normal stress in *Y*-direction

σ_z : total normal stress in *Z*-direction

τ_{xy}: total shear stress in *X*-*Y* plane

τ_{xz} : total shear stress in *X*-*Z* plane

τ_{yz} : total shear stress in *Y*-*Z* plane

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 on a per case basis.

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:

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

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 in which the loading and unloading cycles include a complete pressure and thermal cycle

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

C_w: maximum allowable cumulative fatigue damage ratio

The fatigue damage is to be based on the design life of the tank but not less than 108 wave encounters.

(c) Where required, the fuel containment system is to be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the 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 108 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 the following:

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

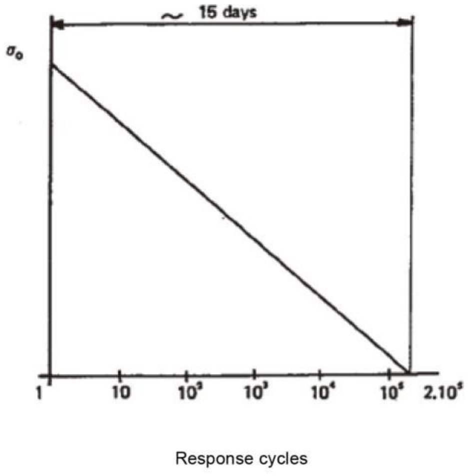
v) the time required for detectable cracks to reach a critical state after penetration through the thickness.

The fracture mechanics are, in principle, to be 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. The crack propagation analysis specified in **6.4.12(2)(g)** with a 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.

Fig. GF6.3 Simplified Load Distribution



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

(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, and the 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, and the 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 criterion applies as a minimum:

Cw is to be less than or equal to 0.1, and the predicted failure development time (from the assumed initial defect until reaching a critical state) is to not be less than three *times* the lifetime of the tank.

(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 following characteristic values.

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 structures

(a) To determine the grades of plates and sections used in hull structures, temperature calculations are to be performed for all tank types. The following assumptions are to be made in these calculations.

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, complete or partial secondary barriers (where required) are 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; 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 defined in **6.4.13-3(6)** and **6.4.13-3(7)** such as thermal and mechanical ageing, compaction, ship motions and tank vibrations 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 comply 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 7.4**. 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 7.4**. 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 all transverse hull structures.

ii) For the longitudinal hull structures 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.

iii) For longitudinal bulkhead between liquefied gas fuel tanks, as an alternative to **ii)** above, 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 such cases, the ship longitudinal strength is to comply with the relevant requirements in other parts for regardless of whether such bulkheads are considered effective.

(d) The means of heating referred to in **(c)** is 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.

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 used for 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 7.1** or **Table 7.2**.

(2) Materials, either non-metallic or metallic but not covered by **Tables 7.1** and **Table 7.2**, 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; however, the test temperature is to not be 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 the fuel containment system

(1) Load-bearing thermal insulation and other materials used in the fuel containment system are to be suitable for the design loads.

(2) Thermal insulation and other materials used in the fuel containment system 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.

(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 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 a 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; however, in cases where backing rings are used, they 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 shells to longitudinal bulkheads of type *C* bi-lobe tanks, tee-welds of the full-penetration type may be accepted.

(b) The bevel preparation of the joints between tank bodies 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 as well as all welds connecting flanges to the vessel or nozzles are to be full-penetration welds.

Note: For vacuum insulated tanks without manholes, longitudinal and circumferential joints are to meet the aforementioned requirements except for the erection weld joints of outer shells which may be one-side welding with backing rings.

2 Design for gluing and other joining processes

The design of joints to be glued (or joined by some process other than welding) is to take into account 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**, and is to be designed in accordance with **6.4.4**.

(2) Structural analysis

(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 hull.

(b) For structural parts (such as structures 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) Tanks with supports are to be designed for the accidental loads specified in **6.4.9-5**. Such 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 in cases where *R*m and *R*e are as defined in **6.4.12(1)(a)iii)**. However, if detailed calculations are carried out for the primary members, the equivalent stress σ_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 at least meet 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) Liquefied gas fuel tank structures are to be reviewed for any potential buckling.

(4) Accidental design condition

(a) Tanks and 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 applicable.

(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 the 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 *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 the following:

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 are to be carried out.

(b) A three-dimensional analysis is to be carried out to evaluate the stress levels, including interaction with the ship 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 conditions

(a) Plastic deformation

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

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

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

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

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

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

where

σ_m: equivalent primary general membrane stress

σ_L : equivalent primary local membrane stress

σ_b : equivalent primary bending stress

σ_g : equivalent secondary stress

f : the lesser of *R*m/*A* or *R*e/*B*

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 σ_m, σ_L, σ_b and σ_g, see also the definition of stress categories in **6.4.15-2(3)(f)**.

The values for *A* to *D* are to have at least the following minimum values.

Table 6.3 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 6.3** may be altered in consideration of design conditions in cases where deemed appropriate by 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 the following:

i) the lesser of *R*m/2 or *R*e/1.2 (for nickel steels and carbon-manganese steels);

ii) the lesser of *R*m/2.5 or *R*e/1.2 (for austenitic steels); and

iii) the lesser of *R*m/2.5 or *R*e/1.2 (for aluminium alloys).

The above figures may be amended in consideration of stress locality, stress analysis methods and design conditions in cases where deemed appropriate by the Society.

The thicknesses of skin plates and stiffener sizes 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 **6.4.12(2)**. The acceptance criteria are 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 applicable.

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 pressure vessels is 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 in **6.4.15-2(3)(f)** are defined 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:

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

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; in addition, 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 the following.

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

where

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

with

σ_m : design primary membrane stress

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

55N/mm^2 (for ferritic-perlitic, martensitic and austenitic steel)

25N/mm^2 (for aluminium alloy (5083-0))

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

h, 0.75*b* or 0.45l

with

h: height of tank (dimension in ship vertical direction) (*m*)

b: width of tank (dimension in ship transverse direction) (*m*)

l: length of tank (dimension in ship longitudinal direction) (*m*)

ρ_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 108 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 for type *C* independent tank minimum design pressure, to a type *A* or type *B* independent tank depending on the configuration of the tank and the arrangement of its supports and attachments.

(2) Shell thickness

(a) In considering 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.

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 the following.

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

where

*P*1: Setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves *P*1 is to be specially considered but is to not, in principle, 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 the weight of domes, the weight of towers and piping, the 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.

iii) If required by the Society, secondary stresses and thermal stresses are to be specially considered.

(3) Ultimate design conditions

(a) Plastic deformation

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

$\sigma_m \leq f$

$\sigma_L \leq 1.5f$

$\sigma_b \leq 1.5f$

$\sigma_L + \sigma_b \leq 1.5f$

$\sigma_m + \sigma_b \leq 1.5f$

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

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

where

σ_m: equivalent primary general membrane stress;

σ_L : equivalent primary local membrane stress;

σ_b : equivalent primary bending stress;

σ_g : equivalent secondary stress; and

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

with R_m and R_e as defined in **6.4.12(1)(a)iii)**. With regard to the stresses σ_m, σ_L, σ_b and σ_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 are 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

i) For type *C* independent tanks where the liquefied gas fuel at atmospheric pressure is below −55°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.

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

(d) Accidental design condition

i) Tanks and 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 applicable.

ii) When subjected to the accidental loads specified in **6.4.9-5**, the stress is to comply with the acceptance criteria specified in **6.4.15-3(3)(a)** modified as appropriate taking into account the lower probability of occurrence.

(e) Marking

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

4 Membrane tanks

(1) Design basis

(a) 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.

(b) 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**, and is to be designed according to **6.4.4**.

(d) The design vapour pressure *P*0 is to not normally exceed 0.025 *MPa*. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, *P*0 may be increased to a higher value but is to be less than 0.070 *MPa*.

(e) The definition of membrane tanks does not exclude designs for 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 *mm*.

(g) The circulation of inert gas throughout the primary and the secondary insulation spaces in accordance with **6.10.1** 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 the following.

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

7) Failure of the supporting hull structure

ii) Fatigue design events

1) Fatigue of membranes including joints and attachments to hull structures;

2) Fatigue cracking of thermal insulation

3) Fatigue of internal structures and their associated supporting structures

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

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 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 or testing for the purpose of determining the ultimate strength and fatigue assessments of the fuel containment system 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 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 the 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 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 of the Rules**, 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 (e.g. 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 the following:

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 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 fuel 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 **6.4.16** and **6.4.1** to **6.4.14**, as applicable. Fuel containment system design according to this **6.4.16** 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

6.5.1 Design

The design of portable fuel tanks is to comply with **6.4.15-3**, and tank supports (container frames or truck chassis) are to be designed for the intended purpose.

6.5.2 Location

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

(1) mechanical protection of the tanks depending on location and cargo operations; and

(2) spill protection and water spray systems for cooling if located on open decks.

6.5.3 Fixing

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

6.5.4 Consideration for Strength and the Effect on Ship Stability

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

6.5.5 Means for Connections

Connections to ship 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 disconnections or ruptures of non-permanent connections.

6.5.7 Pressure Relief Systems

Pressure relief systems for portable fuel tanks are to be connected to fixed venting systems.

6.5.8 Control and Monitoring Systems

Control and monitoring systems for portable fuel tanks are to be integrated into ship control and monitoring systems. Safety systems for portable fuel tanks are to be integrated into ship safety systems (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

The following (1) to (3) are to be satisfied after the connection of portable fuel tanks to ship fuel piping systems.

(1) Each portable tank is to be capable of being isolated at any time with the exception of the pressure relief systems in **6.5.7.**

(2) Isolation of one tank is not to impair the availability of any other tanks.

(3) Tanks are not to exceed their filling limits as given in **6.7**.

6.6 Pressure Relief Systems

6.6.1 General

1 All fuel storage tanks are to be provided with pressure relief systems appropriate to the design of the fuel containment system and the fuel being carried. In addition, fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams that may be subject to pressures beyond their design capabilities are to be provided with suitable pressure relief systems. The pressure control systems specified in **6.8** 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.

6.6.2 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 two 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 17**);

(2) such 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 ship master. This action is to be recorded in the ship log, and at the *PRV*.

7 Pressure relief valves installed on liquefied gas fuel tanks are to be connected to venting systems, which are to be as follows:

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

(2) so arranged to minimize the possibility of water or snow entering the vent system; and

(3) so arranged so 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. Validity of arrangements of vent exits is to be considered for each ship.

8 Outlets from the pressure relief valves are normally to be located at least [10 *m*] [the smaller of B and 25 *m*] from the nearest of the following **(1)**. The validity of vent outlet arrangements is to be considered for each ship.

(1) air intakes, air outlets or openings to accommodation, service and control spaces, or other non-hazardous areas.

Note: The items in square brackets ([ ]) have yet to be finalized and thus may be modified or deleted based on future discussions.

9 Other fuel gas vent outlets are also to be arranged in accordance with **6.6.2-7** and **6.6.2-8**. 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 vent piping systems, means for draining liquid from places where it may accumulate are to be provided. The draining equipment is to prevent the discharged drain from being exposed to humans. 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 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 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 **6.7**, under conditions of 15-degree list and 0.015*L*f trim.

6.6.3 Sizing of Pressure Relieving Systems

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:

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

where

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

F: Fire exposure factor for different liquefied gas fuel types, given as follows.

$F = 1.0$: Tanks without insulation located on deck.

$F = 0.5$: Tanks above deck when insulation is approved by the Society. (Such approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure.)

$F = 0.5$: Uninsulated independent tanks installed in holds.

$F = 0.2$: Insulated independent tanks in holds (or uninsulated independent tanks in insulated holds).

$F = 0.1$: Insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds).

$F = 0.1$: 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 vapourised at relieving conditions (*kJ/kg*)

D_h: 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:

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

where density of air (ρ_{air}) = 1.293 *kg/m*3 (air at 273.15 *K*, 0.1013 *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 **6.6.3-1**.

(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 **6.6.3-1**;

(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*;

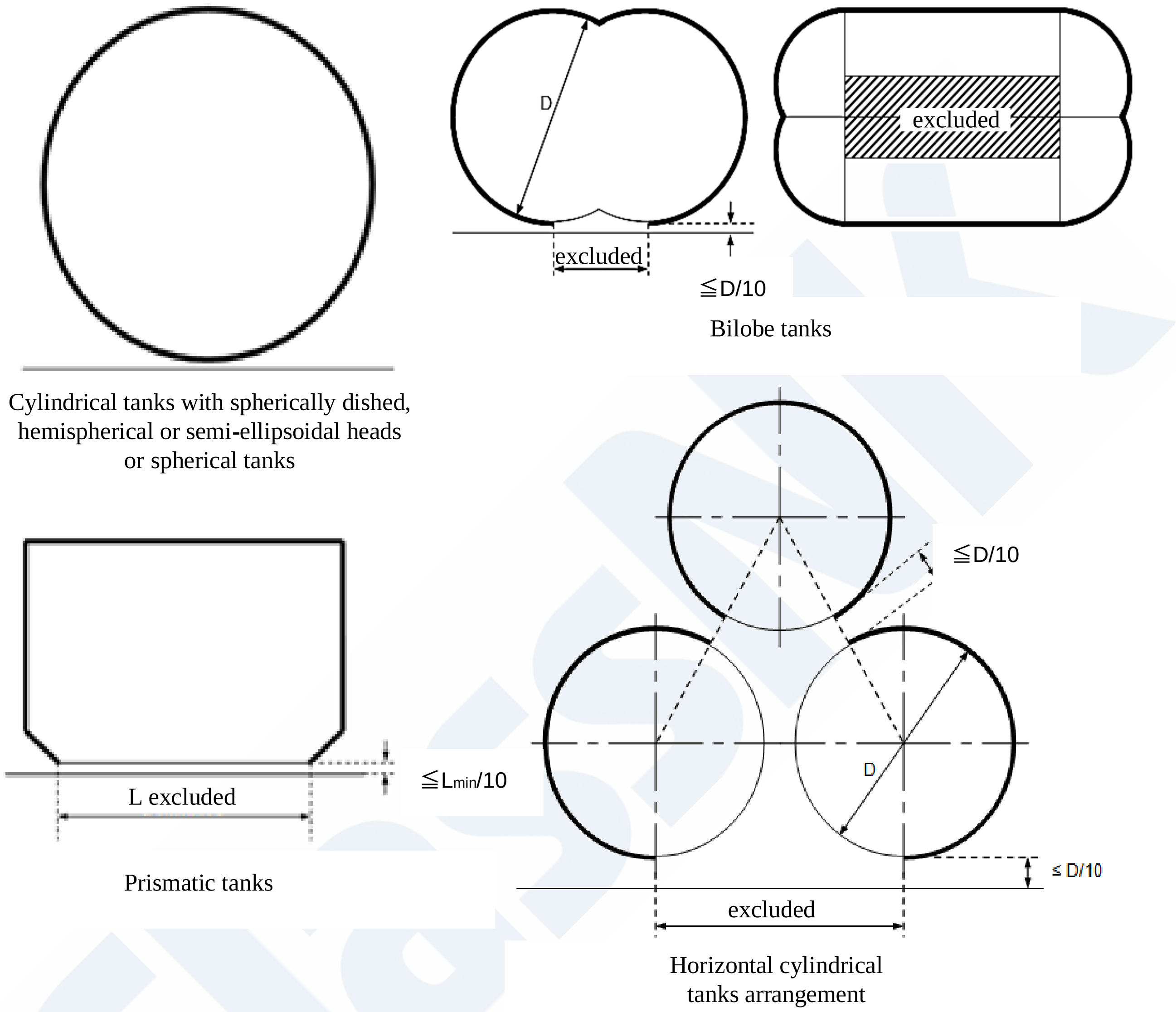
ii) for balanced *PRVs*: 30% of *MARVS*; and

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



6.7 Loading Limit for Liquefied Gas Fuel Tanks

6.7.1 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 **2.2-35**. 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 **2.2-27**, expressed in per cent

FL :filling limit as defined in **2.2-16** expressed in per cent, here 98%

ρ_R : relative density of fuel at the reference temperature

ρ_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%.

6.8 Maintaining Fuel Storage Conditions

6.8.1 Tank Pressure and Temperature Control

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 (i.e. by one of the following methods):

(1) vapour reliquefaction;

(2) vapour thermal oxidation;

(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.

6.8.2 System Design

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

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

6.8.3 Reliquefaction Systems

1 Reliquefaction systems are to be designed and calculated according to **6.8.3-2**. In addition, such systems are to be sufficiently sized to handle cases of low or zero consumption.

2 Reliquefaction systems are to be arranged in one of the following **(1)** to **(4)** ways:

(1) Direct systems where evaporated fuel is compressed, condensed and returned to the fuel tanks;

(2) Indirect systems where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

(3) Combined systems where evaporated fuel is compressed and condensed in a fuel or 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.

6.8.4 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 or no consumption from propulsion or other services of the ship are to be considered.

6.8.5 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.

6.8.6 System Availability

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.

6.9 Atmospheric Control in Fuel Containment Systems

6.9.1 Atmospheric Control in Fuel Containment Systems

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 In order to minimize the risk of ammonia stress corrosion cracking, this can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature *T*. (refer to **7.4.3.7-1**)

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

5 Inert gas utilised for gas freeing of fuel tanks may be provided externally to the ship.

Note: The sampling tube device is to be a closed loop to prevent the release of ammonia gas.

6.10 Atmosphere Control Within Fuel Storage Hold Spaces (Fuel Containment Systems Other Than Type *C* Independent Tanks)

6.10.1 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 the fuel containment system 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 intended 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 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.

6.11 Environmental Control of Spaces Surrounding Type *C* Independent Tanks

6.11.1 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.

6.12 Inerting

6.12.1 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 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.

6.13 Inert Gas Production and Storage on Board

6.13.1 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

7.1.1 General

The goal of this chapter is to ensure the safe handling of fuel under all operating conditions so as to minimize the risk to ship personnel, ships and the environment in consideration of the nature of the products involved.

7.2 Functional Requirements

7.2.1 General

This chapter relates to functional requirements in **3.2.1**, **3.2.5** to **3.2.9** and **3.2.10 and 3.2.17**. 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 Piping, piping systems and associated components, and fuel tanks are to be protected from excessive stresses generated by thermal expansion and from relative displacement between fuel tanks and hull structures.

3 If the gas contains heavier constituents that may condense in the system, arrangements for safely removing such condensation are to be provided.

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.

5 Materials are to be selected in consideration of the corrosiveness of the fuel according to the relevant environment conditions.

6 Fuel piping to be designed to prevent fuel from accumulating in piping in consideration of the characteristics of ammonia. In addition, fuel piping is to be arranged for inerting and gas freeing.

7.3 General Pipe Design

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 structure by thermal isolation, provision is to be made for electrically bonding to the ship structure both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded.

3 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 where necessary to the extent which will minimize condensation of moisture in consideration of leakage confirmation and maintenance.

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.

Note:
・Materials used for piping downstream of pressure relief valves and downstream of bleed valves are to be selected in consideration of the effects of temperature reductions caused by changes in state during fuel release.
・Piping design pressures for piping downstream of pressure relief valves and downstream of bleed valves are to be determined in consideration of the effects of temperature reductions caused by changes in state during fuel release.

7.3.2 Wall Thickness

1 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/mm2*) referred to in **7.3.4**

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 as follows.

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

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.

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 following **(1)** to **(5)** design conditions is 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.

(2) The *MARVS* of the fuel tanks and fuel processing systems.

(3) The pressure setting of the associated pump or compressor discharge relief valve.

(4) The maximum total discharge or loading head of the fuel piping system.

(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 to not 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:

$R_m/2.7$ or $R_e/1.8$

where

R_m: Specified minimum tensile strength at room temperature (*N/mm*2)

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 the following: 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 which considers the 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.

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 in consideration of fatigue potential.

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 Valves and expansion joints used in high-pressure fuel piping systems are to be approved by the Society.

3 Piping systems are 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 −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 −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.

(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 −10°C, slip-on flanges are to not be used in nominal sizes above 100 *mm* and socket welded flanges are to not 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) bellows are to be protected against icing if necessary;

(b) slip joints are to not be used except within the liquefied gas fuel storage tanks; and

(c) bellows are normally to not be arranged in enclosed spaces.

(4) Other connections

Piping connections are, in principle, to be joined in accordance with **7.3.6-4(1)** to **7.3.6-4(3)**; for exceptional cases, however, alternative arrangements approved by Flag State Administrations may be accepted.

7.4 Regulations for Materials

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

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

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

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

(5) **Table 7.5**: Plates and sections for hull structures required by **6.4.13-1(1)(b)**.

(6) Castings for cargo and process piping for design temperatures not lower than 0°C are to be as deemed appropriate by the Society.

2 Materials having melting points below 925°C are to not be used for piping outside of fuel tanks.

3 Metallic materials specified in this chapter according to the requirements in **1.1.2-2**, **Part K of the Rules** are to comply with the requirements of **Part K of the Rules** in addition to those specified in this chapter.

7.4.2 Marking

1 Steels which have satisfactorily complied with the required test are to be marked with identification mark in accordance with the requirements in **Part K of the Rules** and in case the impact test has been required, the impact testing temperature and "*T*" are to be suffixed to the markings. (Example: *KL*33-50*T*. -0*T* as the suffix for 0°C.)

2 For the purpose of the requirements in 7.4.3.1 for which the specified value of the maximum yield point or proof stress and "U" are to be suffixed to the grade mark are to be used in accordance with the requirements in Chapter 3 or Chapter 4, Part K of the Rules.

Note:

Materials used for piping, valves and fittings are to comply with the relevant requirements in **Chapter 7** and as well as with relevant requirements in **Part K of the Rules**. However, for materials used for the piping specified in the following **(1)** to **(5)**, those conforming to *JIS* or other standards deemed appropriate by the Society may be used where they comply only with the requirements in **Chapter 7**.

(1) Pipes, valves and pipe fittings used for cargo piping and process piping with design pressures not exceeding 1 *MPa* and design temperatures of 0°C or more.

(2) Valves and pipe fittings used for cargo piping and process piping with design pressures not exceeding 3 *MPa* and design temperatures of 0°C or more as well as nominal diameters less than 100 *A*.

(3) Pipes, valves and pipe fittings used for accessory piping or instrumentation piping with diameters not exceeding 25 *mm* irrespective of design pressure and design temperature.

(4) Open-ended pipes provided inside and outside cargo tanks, excluding membrane and semi-membrane tanks, with design temperatures of −55°C or higher.

(5) Pipe joints of a butt-welded type and pipe joints of a slip-on sleeve welded type (such as elbows, reducers, tees, bends and sockets, etc.) for which hot forming or heat treatment is carried out during their manufacturing process in accordance with the requirements in **D12.6.1(1)(a)ii), Part D of the Rules** on the condition that they receive approval of use from Society in accordance with **Chapter 12, Part 6 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

Table 7.1 Plates, Pipes (Seamless and Welded) [(1), (2)], Sections and Forgings for Fuel Tanks and Process Pressure Vessels for Design Temperatures Not Lower than 0°C

Chemical composition and heat treatment		
Carbon-manganese steel		
Fully killed fine grain steel		
Small additions of alloying elements by agreement with the Society		
Composition limits to be approved by the Society		
Normalized, or quenched and tempered [(4)]		
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 to not exceed 410 N/mm^2[(5)]	
Toughness (Charpy *V* -notch impact test)		
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27 *J*	
Sections and forgings	Longitudinal test pieces. Minimum average energy value (*KV*) 41 *J*	
Test temperature	Thickness (*mm*)	Test temperature (°C)
	$t \leq 20$	0
	$20 < t \leq 40$ [(3)]	−20

Notes:

(1) For seamless pipes and fittings, the requirements of **Part K of the Rules** apply. 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*2 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 7.2 Plates, Sections and Forgings[(1)] for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below 0°C and down to −55°C
(Maximum Thickness 25 *mm* [(2)])

Chemical composition and heat treatment				
Carbon-manganese steel (Fully killed, aluminium treated fine grain steel)				
Chemical composition (ladle analysis)				
C	M_n	S_i	S	P
0.16% max [(3)]	0.7~1.60%	0.10~0.50%	0.025% max	0.025% max
Optional additions : Alloys and grain refining elements may be generally in accordance with the following				
N_i	C_r	$M0$	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[(4)]				
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/mm2[(5)]			
Toughness (Charpy *V* -notch impact test) :				
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27*J*			
Sections and forgings	Longitudinal test pieces. Minimum average energy value (*KV*) 41*J*			
Test temperature	5°C below the design temperature or −20°C, whichever is lower			

Notes:

(1) The Charpy *V*-notch 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)
$25 < t \leq 30$	10°C below design temperature or −20°C, whichever is lower

$30 < t \leq 35$	15°C below design temperature or −20°C, whichever is lower
$35 < t \leq 40$	20°C below design temperature
$40 < t$	Temperature approved by the 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 that the design temperature is not lower than −40°C

(4) A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

(5) Materials with specified minimum yield stress exceeding 410 *N/mm*2 may be approved by the Society. For these materials, particular attention is to be given to the hardness of the welded and heat affected zones.

Table 7.3 Plates, Sections and Forgings[(1)] for Fuel Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below -55°C and down to -165°C[(2)]
(Maximum Thickness 25 *mm*[(3),(4)])

Minimum design temp. (°C)[(10)]	Chemical composition[(5)] and heat treatment	Impact test temp. (°C)
-60	1.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP[(6)]	See note (11)
-65	2.25%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP[(6)(7)]	See note (11)
-90	3.5%nickel steel - normalized or normalized and tempered or quenched and tempered or TMCP[(6)(7)]	See note (11)
-165	Austenitic stainless steels, such as types 304, 304*L*, 316, 316*L*, 321 and 347 solution treated[(9)]	See note (11)
-165	Aluminium alloys[(10)]: such as type 5083 annealed	Not required
Tensile and toughness (impact) test regulations		
Sampling frequency		
Plates	Each "piece" to be tested	
Sections and Forgings	Each "lot" to be tested	
Toughness (Charpy *V*- Notch Impact Test):		
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27*J*	
Sections and Forgings	Longitudinal test pieces. Minimum average energy value (*KV*) 41*J*	

Notes

(1) The impact test required for forgings used in critical applications 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 (℃)
$25 < t \leq 30$	10℃ below design temperature
$30 < t \leq 35$	15℃ below design temperature
$35 < t \leq 40$	20℃ below design temperature

In no case is the test temperature to be above that indicated in **Table 7.3**.

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 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) The impact test may be omitted subject to agreement with the Society.

(9) For aluminimum alloys other than type 5083, additional tests may be required to verify the toughness of the material.

(10) The design temperature may be higher than the minimum design temperature, tanking into account the characteristics of ammonia.

(11) The impact test temperature is to be the temperature deemed appropriate by the Society in accordance with the design temperature, where required.

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

(Maximum Thickness 25 *mm*)

Minimum design temp.[9] (°C)	Chemical composition[5] 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.[6]	See note (4)	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	See note (10)	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	See note (10)	34
-165	Austenitic stainless steels, such as types *304*, *304L*, *316*, *316L*, *321*, and *347*. Solution treated.[7]	See note (10)	41
	Aluminium alloys[8]; 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) Impact tests may be omitted subject to agreement with the Society.

(8) For aluminimum alloys other than type 5083, additional tests may be required to verify the toughness of

the material.

(9) The design temperature may be higher than the minimum design temperature, tanking into account the characteristics of ammonia.

(10) The impact test temperature is to be the temperature deemed appropriate by the Society in accordance with the design temperature, where required.

Table 7.5 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							
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 **Table 7.2** except that the thickness limitation given in **Table 7.2** and note 2 of that table does not apply.							

Note:

×: means steel grade not to be used.

7.4.3 Material Requirements for Corrosion

Materials which may be exposed to fuel during normal operations are to be resistant to the corrosive action of ammonia. In addition, mercury, copper, copper alloys and zincare not to be used for the construction of fuel tanks as well as associated pipelines, valves, fittings and other items of equipment normally in direct contact with the fuel liquid or vapour.

7.4.4 Requirements for Stress Corrosion Cracking

Since anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon manganese steel or nickel steel, the measures detailed in this **7.4.4** are to be taken as appropriate to minimize the risk of this occurring.

7.4.4.1 Requirements for Using Carbon Manganese Steel

Where carbon manganese steel is used, cargo tanks, process pressure vessels and cargo piping are to be made of fine-grained steel with a specified minimum yield strength not exceeding 355 *N*/*mm*2 and with an actual yield strength not exceeding 440 *N*/*mm*2. One of the following constructional or operational measures is also to be taken.

(1) Lower strength material with a specified minimum tensile strength not exceeding 410 *N*/*mm*2 is to be used.

(2) Cargo tanks, etc. are to be post weld stress relief heat treated.

(3) Carriage temperature is to be maintained preferably at a temperature close to the product boiling point of −33°C but in no case at a temperature above −20°C.

(4) Ammonia is not to contain less than 0.1% *w*/*w* water.

7.4.4.2 Heat Treatment for Carbon Manganese Steels with Higher Yield Properties

If carbon manganese steels with higher yield properties are used other than those specified in **7.4.4.1**, the completed cargo tanks, piping, etc. are to be given a post weld stress relief heat treatment.

7.4.4.3 Heat Treatment for Process Pressure Vessels

Process pressure vessels and piping for the condensate parts of refrigeration systems are to be given a post-weld stress relief heat treatment when made of materials referred to in this **7.4.4**.

7.4.4.4 Mechanical Properties of the Welding Consumables

The tensile and yield properties of welding consumables are, in principle, not to be less than those of the tank or piping material. In addition, the weld consumable are to be made of equivalent materials and only exceed the tensile and yield properties of the tank or piping material as small an amount as practicable.

7.4.4.5 Unsuitable Materials to Use

Nickel steel containing more than 5% nickel, and carbon manganese steel not complying with **7.4.4.1** and **7.4.4.2** are particularly susceptible to ammonia stress corrosion cracking and are not to be used for containment and piping systems for the carriage of this product.

7.4.4.6 Requirements for Using Nickel Steel Containing Not More Than 5% Nickel

Nickel steel containing not more than 5% nickel may be used, provided that the carriage temperature complies with the requirements specified in **7.4.4.1(3)**.

7.4.4.7 Dissolved Oxygen Content

In order to minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2.5 *ppmw/w*. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature *T* in the **Table 7.5**.

Table 7.5

T (°C)	*O*2 (%*v/v*)
−30 and below	0.90
−20	0.50
-−10	0.28
0	0.16
10	0.10
20	0.05
30	0.03

Note: Oxygen percentages for intermediate temperatures may be obtained by direct interpolation.

Chapter 8 BUNKERING

8.1 Goal

8.1.1 General

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

8.2 Functional Requirements

8.2.1 General

This chapter relates to functional requirements in **3.2.1** to **3.2.11** and **3.2.13** to **3.2.18**. In addition, **8.2.2** applies.

8.2.2 Piping Systems

Piping systems for transferring fuel to storage tanks are to be designed so that any leakage from the piping system cannot cause danger to ship personnel, ships, or the environment.

8.3 Bunkering Stations

8.3.1 General

1 Bunkering stations are to be located on open decks so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations are to be subject to special consideration with respect to risk assessment.

2 Closed or semi-enclosed bunkering stations are to be gastight towards adjacent spaces. The term “adjacent” includes linear contact and point contact.

3 Air intakes and openings in accommodation spaces, service spaces, engine rooms and control stations are not be located in hazardous areas associated with bunkering stations.

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

5 Bunkering piping is to not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations. Where bunkering piping is arranged in spaces other than closed non-hazardous spaces, bunkering piping is to pass through a secondary enclosure .

6 Arrangements are to be made for safe management of any spilled fuel. A drip tray is to be fitted at the bunkering pipe connection to contain the spilled fuel. Where each tray is arranged open deck, the tray is to be fitted with a means for draining rain water.

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

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

8.3.2 Ship Fuel Hoses

1 In case of storing fuel hoses on board, **8.3.2** is to be satisfied.

2 Bunkering hoses for fuel transfer are to be compatible with fuel.

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

4 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.

5 Fuel hoses are to be stowed in consideration of ventilation.

8.4 Manifolds

8.4.1 Manifolds

1 Bunkering manifolds are to be designed to withstand the external loads generated during bunkering. The connections at bunkering stations are to be of dry-disconnect type equipped with additional safety dry break-away couplings for self-sealing quick releases. The couplings are to be of a standard type.

2 Water spray systems is to be arranged at connections around bunkering manifolds so as to prevent any diffusion of ammonia.

8.5 Bunkering Systems

8.5.1 Purging

Arrangements for purging fuel bunkering lines with inert gas are to be provided.

8.5.2 Prevention of Gas Release

Bunkering systems are to be so arranged that no gas is discharged to the atmosphere during the 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 on every bunkering line close to the connecting point. It is to be possible to operate the remote valve at the control location for bunkering operations or from another safe location.

8.5.4 Drainage

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

8.5.5 Inerting and Gas Freeing

Bunkering lines are to be suitably arranged for inerting and gas freeing.

8.5.6 Isolation of Bunkering Lines

In cases where bunkering lines are arranged with crossovers, 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 Links (*SSL*)

Ship-shore links (*SSL*) or equivalent means for automatic and manual *ESD* communication to the bunkering source are to be provided.

8.5.8 Adjustment of Valve Closure Time

If not demonstrated to be required at a higher value due to pressure surge considerations, the default time as calculated in accordance with **16.7.2-7** 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

9.1.1 General

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

9.2 Functional Requirements

9.2.1 General

This chapter is related to the 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 Fuel supply systems are to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection. The causes and consequences of fuel release are to be given special consideration when carrying out the risk assessment required by **4.2**.

2 Piping systems for transferring fuel to fuel consumers are to be so designed that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to ship personnel, ships, or the environment.

3 Fuel lines are to be installed and protected so as to minimize the risk of injury to ship personnel and damage to the ship in the case of leakage.

4 All fuel piping is to be suitably arranged for inerting and gas freeing.

9.3 Fuel Supply Redundancy

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 fuel tanks to fuel consumers 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 single fuel installations, one tank may be accepted, regardless of **9.3.2** above, in cases where the tank is a type *C* tank, and two completely separate tank connection spaces are installed for the one tank.

9.4 Safety Functions of Gas Supply Systems

9.4.1 Valve Location

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 Fuel Valves

The main gas supply line to each fuel consumer or set of fuel consumers are to be equipped with either a manually operated stop valve and an automatically operated "master 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 located outside of the machinery space containing the fuel consumers and placed as near as possible to the installation for heating the gas (if fitted). The master fuel valve is automatically to cut off the fuel supply when activated by the safety system required in **15.2.2-2**.

9.4.3 Master Fuel Valve Operation

The automatic master 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 Double Block and Bleed Valve Arrangements

Fuel consumers are to be provided with "double block and bleed valve" arrangements. In addition, such 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.

(1) The two shutoff valves are to be in series in the fuel pipe to the fuel consumer. The bleed valve is to be in a pipe that vents to a safe location in the open air that portion of the fuel piping that is between the two valves in series; or

(2) The functions of one of the shutoff valves in the series and the bleed valve can be incorporated into a single valve body so arranged that the flow to the fuel consumer will be blocked and the ventilation opened.

9.4.5 Double Block and Bleed Valve Shutoff

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

9.4.6 Double Block and Bleed Valve Use

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

9.4.7 Ventilation of Gas Supply Branches Downstream of Double Block and Bleed Valves

1 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.

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

Inert gas supply lines are to be fitted with two shutoff valves in a series with venting valves provided in between (double block and bleed valves) and closable non-return valves installed between the double block and bleed arrangements and fuel systems.

9.4.8 Shutdown Valves for Gas Supply Lines

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

9.4.9 Valve Functions

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

9.5 Fuel Temperature and Pressure Control

1 Design and fabrication are to be provided to ensure that ammonia fuel does not cause unintentional phase changes within the fuel supply system.

2 When used as gas fuel by fuel consumers, the ambient temperature is to not fall below the dew point at the maximum operating pressure.

3 When used as liquid fuel by fuel consumers, fuel supply pressure is to be sufficient to maintain the liquid state.

9.6 Fuel Distribution Outside of Machinery Spaces

9.6.1 Fuel Pipes

1 Where gaseous fuel pipes pass through enclosed spaces in the ship, they are to be protected by a secondary enclosure. Such enclosures may be ventilated ducts or double wall piping systems; however, such ducts or double wall piping systems are to be mechanically underpressure ventilated with 30 *air changes per hour* as required by **13.8**, and the gas detection required by **15.8** is to be provided. Other solutions providing an equivalent safety level may also be accepted by the Society.

2 The requirements of **-1** above may be waived for piping systems located in fuel preparation rooms or tank connection spaces.

3 Secondary enclosures are to be able to withstand the maximum pressure that may build up in the enclosure in the case of leakage from fuel piping. For this purpose, secondary enclosures may need to be arranged with pressure relief systems that prevent enclosures from being subjected to pressures above their design pressures.

4 Where the gas detection required by **15.8.1.2** is not suitable for the intended purpose, secondary enclosures around liquefied fuel pipes are to be provided with leakage detection by means of pressure or temperature monitoring systems, or any combination thereof.

9.6.2 Vent Pipes

The requirements in **9.6.1** need not be applied to fully welded fuel gas vent pipes led through mechanically ventilated spaces.

9.7 Fuel Supply to Fuel Consumers in Gas-safe Machinery Spaces

9.7.1 Fuel Piping

Fuel piping in gas-safe machinery spaces is to be completely enclosed by double pipes or ducts meeting one of the following **(1)** to **(3)**conditions.

(1) The 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 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 fuel valve and the engine is automatically purged with inert gas when the master fuel valve is closed.

(2) The 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* on the condition that arrangements for the automatic filling of the duct with nitrogen upon detection of gas are provided. Fan motors are to comply with the required explosion protection in the installation area, and ventilation outlets are to be covered by protection screens and installed at locations where no flammable gas-air mixture may be ignited.

(3) Other solutions providing an equivalent safety level may also be accepted by the Society.

9.7.2 Connecting

Connections of piping and ducting to injection valves are to be completely covered by the ducting. Such arrangements are to facilitate the replacement and overhaul of injection valves and cylinder covers. In addition, double ducting is required for all gas pipes installed on the engine itself up until the points where gas is injected into chambers.

9.8 The Design of Ventilated Ducts and Outer Pipes Against Inner Pipe Gas Leakage

9.8.1 Design Pressure of Outer Pipes and Ducts

1 The design pressures of outer pipes and ducts of fuel systems are to not be less than the maximum working pressures of the inner pipes. Alternatively, for fuel piping systems with working pressures greater than 1.0 *MPa*, the design pressures of outer pipes and ducts are not to be less than the maximum built-up pressures arising in annular spaces in consideration of local instantaneous peak pressures in way of any ruptures) and ventilation arrangements.

2 Double wall pipes and ducts are to be gastight towards adjacent spaces.

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

$p0$: 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 CH4

2 The tangential membrane stress of a straight pipe is to not exceed the tensile strength divided by 1.5 (R_m/1.5) when subjected to the above pressures. The pressure ratings of all other piping components 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 may be used. Test reports are then to be submitted.

9.8.3 Verification of Strength

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

9.8.4 Duct Testing and Dimensions

For low-pressure fuel piping, ducts are to be sized for design pressures not less than the maximum working pressures of the fuel pipes. In addition, ducts are to be pressure tested to show that they can withstand the expected maximum pressures at fuel pipe ruptures.

9.9 Compressors and Pumps

9.9.1 Bulkhead Penetrations

If compressors or pumps are driven by shafting passing through bulkheads or decks, the bulkhead penetrations are 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 but are not limited to the following **(1)** to **(4)**:

(1) environmental impact,

(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 is liquefied gas introduced into gas control sections or gas-fuelled machinery unless the machinery is designed to operate with gas in the liquid state.

9.9.4 Accessories and Instrumentation

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

Chapter 10 POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS

10.1 Goal

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

10.2.1 General

This chapter is related to functional requirements in **3.2.1, 3.2.2**, **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 Exhaust systems are to be configured to prevent any accumulation of unburnt fuel.

2 Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, engine components or systems containing or likely to contain ignitable fuel and air mixtures are to be fitted with suitable pressure relief systems. Dependent on the particular engine design, this may include air inlet manifolds and scavenge spaces.

3 Explosion venting is to be led away from any locations where ship personnel may normally be present.

4 All fuel consumers are to have separate exhaust systems.

5 Connections of gas piping and ducting to fuel injection valves are to be completely covered by continuous double piping constructions or ducting. Such arrangements are to facilitate the replacement and overhaul of injection valves and cylinder covers. In addition, double ducting is required for all fuel pipes installed on the engine itself up until the points where fuel is injected into chambers.

6 Leaked fuel in secondary spaces is to be properly treated.

10.3 Piston-type Internal Combustion Engines

10.3.1 General

1 Exhaust systems are to be equipped with explosion relief ventilation sufficiently sized to prevent excessive explosive pressures in the event of the ignition failure of one cylinder followed by the ignition of the unburnt gas in the system.

2 For trunk type engines (i.e. engines without diaphragms between their crankcases and cylinder spaces), 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 Engines other than two-stroke crosshead diesel engines are to be fitted with vent systems for crankcases and sumps that are independent of the vent systems for other engine crankcases and sumps. Gas extracted from such vent systems is to be vented into the atmosphere from safe locations.

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 expel the leaked fuel in order to prevent gas dispersion.

5 For engines fitted with ignition systems, correct operation of the ignition system for each unit is to be verified prior to admission of gas fuel.

6 A means is to be provided to monitor and detect poor combustion or misfiring. In the event of any such detection, gas operation may be allowed, provided that the gas supply to the concerned cylinder is shut off and engine operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations.

7 For engines starting on ammonia fuel, , the fuel supply valve is to be automatically shut off in cases where combustion is not been detected by engine monitoring systems within an engine specific time after the opening of the fuel supply valve. Means to ensure that any unburnt fuel mixture is purged away from exhaust systems is to be provided.

8 Consideration is to be given to the following with respect to ammonia fuel injection valves.

(1) Ammonia fuel injection valves are to possess satisfactory operating characteristics and durability for the assumed service period.

(2) Ammonia fuel valves are to be provided with sealing systems to effectively to effectively prevent fuel from leaking through spaces around valve spindles.

(3) Appropriate means are to be provided in cases where fuel injection valve actuating oil is required to be kept clean.

10.3.2 Dual Fuel Engines

1 In the case of the shut off of the ammonia fuel supply, engines are to be capable of continuous operation by oil fuel only without interruption.

2 An automatic system is to be fitted to switch over from ammonia fuel operation to oil fuel operation and vice versa with a minimum fluctuation of engine power, and an acceptable degree of reliability is to be demonstrated through testing. In the case of unstable engine operation when gas firing, engines are to automatically changeover to oil fuel mode. In addition, manual changeover to the oil fuel mode is to always be possible.

3 In the case of normal stoppage or emergency shutdown, the ammonia fuel supply is to be shut off no later than the shut off of the ignition source. In addition, it is to not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the engine itself.

10.3.3 Ammonia-only Engines

In the case of normal stoppage or emergency shutdown, the ammonia fuel supply is to be shut off no later than the shut off of the ignition source. In addition, it is to not be possible to shut off the ignition source without first or simultaneously closing the ammonia supply to each cylinder or to the engine itself.

10.3.4 Multi-fuel Engines

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

2 An automatic system is to be fitted to switch over from one fuel operation to an alternative fuel operation with a minimum fluctuation of engine power, and an acceptable degree of reliability is to be demonstrated through testing. In the case of unstable engine operation when using a particular fuel, engines are to automatically changeover to an alternative fuel mode. In addition, manual change
over to the alternative fuel mode is to always be possible.

10.3.5 Ignition Medium and Main Fuel

In applying **10.3.2** to **10.3.4**, the combination of the ignition medium and main fuel for engines is to be as shown in **Table 10.1**.

Table 10.1 Ammonia Combustion Engines

	Ammonia Only		Dual Fuel	Multi-fuel
Ignition medium	Spark	Pilot fuel	Pilot fuel	N/A
Main fuel	Ammonia	Ammonia	Ammonia or oil fuel, or both	Ammonia or liquid fuel other than oil fuel, or both

10.4 Main and Auxiliary Boilers

10.4.1 Forced Draught Systems

Boilers are to have dedicated forced draught systems. In addition, crossovers 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

Main and propulsion boilers are to be provided with automatic systems to changeover from gas fuel operation to oil fuel operation without interruption of boiler firing.

10.4.5 Combustion

Gas nozzles and burner control systems are to be configured so that gas fuel can only be ignited by an established oil fuel flame except in those cases approved by the Society in which the boiler and combustion equipment is designed to ignite on gas fuel.

10.4.6 Fuel Cut-off

Arrangements are to be provided to ensure that the gas fuel flow to burners is automatically cut off unless satisfactory ignition has been established and maintained.

10.4.7 Valves

Manually operated shutoff valves are to be fitted to gas burner fuel pipes.

10.4.8 Inerting

Arrangements are to be provided for automatically purging the gas supply piping to burners by inert gas after extinguishing the burners.

10.4.9 Monitoring Systems

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

10.4.10 Re-ignition

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

10.4.11 Manual Purge

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

Chapter 11 FIRE SAFETY

11.1 Goal

The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of ammonia as ship fuel.

11.2 Functional Requirements

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

11.3 General Requirements

This chapter is to be applied addition to **Part R of the Rules**.

11.4 Fire Protection

1 Fuel preparation rooms are to be regarded as machinery spaces of category *A* for fire protection purposes.

2 Spaces containing fuel containment systems are to be separated from the machinery spaces of category *A* or other rooms with high fire risks. Such separation is to be done by cofferdams of at least 900 *mm* insulated to *A*-60 class standards. For type *C* tanks, fuel storage hold spaces may be treated as cofferdams provided that:

(1) the type *C* tanks are not located directly above machinery spaces of category *A* or other rooms with high fire risk; and

(2) the minimum distance to the "*A*-60" boundary from the outer shell of the type *C* tank or the boundary of tank connection spaces, if any, is not less than 900mm.

3 When determining the insulation of spaces containing fuel containment systems from other spaces considered to be lower fire risks, fuel containment systems are to be treated as machinery spaces of category *A* in accordance with **Chapter 9, Part R of the Rules**.

4 Fuel storage hold spaces are to not be used for machinery or equipment that may have a fire risk.

5 Closed or semi-enclosed bunkering stations are to be separated by *A*-60 class divisions from machinery spaces of category *A*, accommodation spaces, control stations and high fire risk spaces; however, this does not include spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces in which the insulation standard may be reduced to class *A*-0.

11.5 Fire Mains

The water spray systems required by **11.6** below may be part of fire main systems, provided that the required fire pump capacity and working pressure are sufficient for the simultaneous operation of both the required numbers of hydrants and hoses as well as the water spray system itself.

11.6 Water Spray Systems

1 Water spray systems are to be installed for cooling and fire prevention to cover exposed parts of fuel storage tanks located on open decks.

2 Water spray systems are to be designed to cover all areas as specified **-1** 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. For structures having no clearly defined horizontal or vertical surfaces, the capacity of the water spray systems are not to be less than the projected horizontal surface multiplied by 10 $l/min/m^2$.

3 Stop valves are to be fitted in water spray application main supply lines, at intervals not exceeding 40 *m*, for the purpose of isolating damaged sections. Alternatively, water spray systems may be divided into two or more sections that may be operated independently, provided that the necessary controls are located together in readily accessible positions not likely to be inaccessible in the case of fire in the areas protected.

4 Water spray pump capacity is to be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified **-1** above.

5 If the water spray system is not part of the fire main system, a connection to the ship fire main through a stop valve is to be provided.

6 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 readily accessible positions not likely to be inaccessible in the case of fire in the areas protected.

7 Nozzles are to be of an approved full-bore type and are to be arranged to ensure an effective distribution of water throughout the areas protected.

11.7 Fire-Extinguishing System in Fuel Preparation rooms

Fuel preparation rooms containing pumps or compressors or other potential ignition sources are to be provided with a fixed fire-extinguishing system.

11.8 Dry Chemical Powder Fire-extinguishing Systems

1 Permanently installed dry chemical powder fire-extinguishing systems are to be installed in closed or semi-enclosed bunkering station areas to cover all possible leak points. The capacity is to be at least 3.5 *kg*/*s* for a minimum of 45 *s*, and the system is to be arranged for easy manual release from a safe location outside the area protected.

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

Chapter 12A EXPLOSION PREVENTION

12A.1 Goal

12A.1.1 General

The goal of this chapter is to provide for the prevention of explosions and to limit the effects of explosions.

12A.2 Functional Requirements

12A.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, **12A.2.2** applies.

12A.2.2 Additional Requirements

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

(1) reducing the number of ignition sources, and

(2) reducing the probability of ignitable mixture formation.

12A.3 General

12A.3.1 General

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

> Note: Electrical equipment is to be explosion-protected of a certified safe type complying with **2.16, Part H of the Rules**. In addition, such equipment is to be a gas vapour group of IIA or higher and a temperature classification of T1 or the equivalent.

12A.3.2 Electrical Equipment and Cables

Electrical equipment and wiring are, in principle, to not be installed in hazardous areas unless essential for operational purposes in accordance with **4.2.4**, **Part H of the Rules**.

12A.4 Hazardous Areas

12A.4.1 General

Area classification is a method of analysing and classifying areas where explosive gas atmospheres may occur. The object of such classification is to allow the selection of electrical apparatuses capable of being safely operated safely in such areas.

12A.4.2 Hazardous Area Classification

In order to facilitate the selection of appropriate electrical apparatuses and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2 in accordance with **12.5**.

12A.4.3 Ventilation Ducts

Ventilation ducts are to have the same area classification as the spaces they serve.

12A.5 Hazardous Area Zones

12A.5.1 Zone 0 Hazardous Areas

This zone includes but is not limited to the interiors of fuel tanks, pipework for pressure-relief or other venting systems for fuel tanks, and pipes and equipment containing fuel.

12A.5.2 Zone 1 Hazardous Areas

This zone includes but is not limited to the following.

(1) Tank connection spaces, fuel storage hold spaces and interbarrier spaces.

(2) Fuel preparation room arranged with ventilation according to **13.6**.

(3) Semi-enclosed spaces on deck, 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) Semi-enclosed spaces on deck, of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into Zone 1 hazardous areas.

(5) Enclosed or semi-enclosed spaces in which pipes containing fuel are located (e.g. ducts around fuel pipes, semi-enclosed bunkering stations).

(6) Spaces protected by airlocks are considered to be non-hazardous areas during normal operation, provided that the equipment contained therein required to operate following loss of differential pressure between protected spaces and hazardous areas is certified as being suitable for Zone 1 hazardous areas.

12A.5.3 Zone 2 Hazardous Areas

This zone includes but is not limited to the following:

(1) spaces containing bolted hatches to tank connection spaces, and

(2) airlocks.

Chapter 12B TOXIC HAZARDOUS AREAS

12B.1 Purpose

12B.1.1 General

The goal of this chapter is to minimize the effects of ammonia toxicity on ships and humans.

12B.2 Functional requirements

12B.2.1 General

This chapter is related to functional requirements in **3.2.2**, **3.2.4**, **3.2.5**, **3.2.12**, **3.2.14**, **3.2.16** and **3.2.18**.

12B.3 General Requirements

12B.3.1 Ship Area Classification

1 Classification of toxic hazardous areas is a means of analyzing and classifying area where ammonia gas may occur. The purpose of the classification is to take safety measures according to the type of hazardous area.

2 Toxic hazardous areas refers to the following areas.

(1) Toxic hazardous areas

Zone 0: Areas or spaces in which an ammonia is either continuously present or is present for long periods of time.

Zone 1: Areas or spaces in which ammonia gas that is hazardous to human health is regularly generated or rarely generated under normal conditions

Zone 2: Areas or spaces in which ammonia gas that is hazardous to human health is to not likely be generated under normal conditions, but the areas around Zone 1 areas in which such gas can only exist for a short time if generated.

(2) Non-toxic hazardous areas

Areas other than the above in which there is no ammonia gas generated that is hazardous to human health.

(3) Classification methods for toxic hazardous areas is to be in accordance with **H4.2.3, Part H of the Guidance**.

12B.4 Classification of Toxic Hazardous Areas

12B.4.1 Zone 0 Toxic Hazardous Areas (Enclosed Spaces)

This zone includes but is not limited to the interiors of fuel tanks, pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

12B.4.2 Zone 1 Toxic Hazardous Areas (Enclosed Spaces)

This zone includes but is not limited to the following

(1) Tank connection spaces, fuel storage hold spaces and interbarrier spaces

(2) Fuel preparation room arranged with ventilation according to **13.6**

(3) Enclosed or semi-enclosed spaces in which pipes containing fuel are located (e.g. ducts around fuel pipes, semi-enclosed bunkering stations)

(4) Spaces protected by airlocks are considered to be non-hazardous areas during normal operations, provided that the equipment contained therein required to operate following loss of differential pressure between protected spaces and hazardous areas is certified as suitable for Zone 1 toxic hazardous areas

12B.4.3 Zone 2 Toxic Hazardous Areas (Enclosed Spaces)

This zone includes but is not limited to the following:

(1) spaces containing bolted hatch to tank connection spaces

(2) airlocks

12B.4.4 Toxic Hazardous Areas (Open Decks)

1 Toxic hazardous areas on open decks are to be classified at least as follows; however, it is to be considered whether the following toxic hazardous areas are valid for each ship.

(1) Zone 1 (on open decks) areas include followings, but are not limited to:

(a) Areas on open decks, or semi-enclosed spaces on decks, 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.

(b) Areas on open decks 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 areas.

(c) Areas on the open decks within spillage coamings surrounding gas bunker manifold valves and [3 *m*] beyond these, up to a height of [2.4 *m*] above deck.

(d) Except for type *C* tanks, areas within [2.4 *m*] of the outer surfaces of fuel containment systems for which such surfaces are exposed to weather.

(2) Zone 2 (on open decks) areas include followings, but are not limited to:

(a) Areas within [1.5 *m*] surrounding open or semi-enclosed Zone 1 areas.

Note: Items in square brackets ([ ]) have yet to be finalized and thus may be modified or deleted as deemed necessary based on future discussions.

2 The level of ammonia gas that is hazardous to human health is based on the following **Table 12B3.1** or **Table 12B3.2**. The standard value can be set by the agreement of the parties, depending on the operation at each location. However, the reference values used for reference may be published by Flag State Administrations, internationally recognized standard organizations or laboratories.

Note: Standards for concentration in Zone 1 and Zone 2 hazardous locations may be the same.

Table 12B 3.1 EPA Acute Exposure Guideline Levels

	10 min	30 min	60 min	4 h	8 h
AEGL 1	30	30	30	30	30
AEGL 2	220	220	160	110	110
AEGL 3	2700	1600	1100	550	390

AEGL 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. Such effects, however, are not disabling, are transient and are reversible upon cessation of exposure.

AEGL 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL 3: Life-threatening health effects or death.

Table 12B3.2 Standard Values Surveyed by the Society

Ammonia concentration (*ppm*)	Effects on the body
5–10	Smell odor
50	Find distasteful
100	Feel stimulus
200–300	Stimulate the eyes and throat
300–500	Only able to endure for short periods of time (20 to 60 *min.*)
2,500–5,000	Life threatening in a short time (about 30 *min.*)
5,000–10,000	Breathing stop, death in short time

Chapter 13 VENTILATION

13.1 Goal

13.1.1 General

The goal of this chapter is to provide for ventilation required for the safe working environment of ship personnel as well as the safe operation of gas-fuelled machinery and equipment.

13.2 Functional requirements

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

13.3.1 Ventilation of Hazardous Areas

1 Ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces.

2 Ventilation is to properly function at all temperatures and environmental conditions the ship will be operating in.

3 Leaked gas is to be properly discharged to a safe location and not allowed to accumulate in hazardous spaces.

4 Spaces required to be entered during normal operations are to always be ventilated.

5 Mechanical ventilation in spaces not normally entered is to automatically activate after the detection of gas. In addition, mechanical ventilation in spaces is to capable of being manually started manually for maintenance purposes, etc.

13.3.2 Electric Motors for Ventilation Fans

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

13.3.3 Design of Ventilation Fans Serving Spaces Containing Gas Sources

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

(1) Ventilation fans are to not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts (in way of fans only) are to be one of the following types of non-sparking construction:

(a) impellers or housings made of non-metallic materials with due regard being paid to the elimination of static electricity;

(b) impellers and housings made of non-ferrous metals;

(c) impellers and housings made of austenitic stainless steel;

(d) impellers made 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 with 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 is the casing to be less than 0.1 of the diameter of the impeller shaft in way of the bearing. The gap need not be more than 13 *mm* but is to not be less than 2 *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 to be a sparking hazard and is to not be used.

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 would otherwise be considered non-hazardous in the absence of such an inlet. Where the inlet duct passes through a more hazardous space, the duct is to be gastight and is to not be underpressured relative to the space.

13.3.6 Air Inlets for Non-Hazardous Enclosed Spaces

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 gastight and is to not be underpressured relative to the space.

13.3.7 Air Outlets for Non-hazardous Spaces

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

13.3.8 Air Outlets for Hazardous Enclosed Spaces

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

2 Air outlets for spaces where ammonia leakage may result from a single failure (such as enclosed and semi-enclosed bunkering stations, tank connection spaces, fuel preparation rooms, double pipes and ducts) are to be located as described below. The validity of arrangements of vent exits is to be considered for each ship.

(1) At least 4 m above the weather deck, working areas and walkways.

(2) At least 10 m (horizontal distance) from air intakes, exhausts and openings in accommodation spaces, service spaces and control stations, or other non-hazardous spaces.

13.3.9 Required Capacity for Ventilation Plants

The required capacity for ventilation plants is normally based on the total volume of the space served. An increase in required ventilation capacity may be necessary for rooms with complex layouts.

13.3.10 Non-hazardous Areas with Entry Openings to Hazardous Areas

Non-hazardous areas with entry openings to hazardous areas are to be arranged with airlocks and be maintained at overpressure relative to the external hazardous area. In addition, overpressure ventilation is to be arranged according to the following.

(1) During initial start-up or after loss of overpressure ventilation, , the following **(a)** and **(b)** are required before energizing any electrical installations not certified safe for the space in the absence of pressurization:

  (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 overpressure ventilation is to be monitored and the following **(a)** and **(b)** are required in the event of failure:

  (a) an audible and visual alarm is to be given at manned locations; and

  (b) automatic or programmed disconnection of electrical installations according to a standard recognized by the Society is required if overpressure cannot be immediately restored.

13.3.11 Non-hazardous Areas with Entry Openings to Hazardous Enclosed Spaces

Non-hazardous areas with entry openings to hazardous enclosed spaces are to be arranged with airlocks and the hazardous spaces are to be maintained at underpressure relative to the non-hazardous area. Operation of the extraction ventilation in the hazardous spaces is to be monitored and the following **(1)** and **(2)** are required in the event of failure:

(1) an audible and visual alarm is to be given at manned locations; and

(2) automatic or programmed disconnection of electrical installations according to a standard recognized by the Society is required if underpressure cannot be immediately restored in the non-hazardous enclosed space.

13.4 Tank Connection Spaces

13.4.1 Mechanical Forced Ventilation Systems

Tank connection spaces are to be provided with effective mechanical forced ventilation systems of an extraction type, and such systems are to have a ventilation capacity of at least 30 *air changes per hour*.

13.4.2 Ventilation Fans

The number and power of ventilation fans in tank connection spaces are to not be such that capacity is reduced by more than 50% of total ventilation capacity even if the following fans cannot be used.

(1) Fans with separate circuits from main switchboards or emergency switchboards.

(2) Groups of fans with common circuits from main switchboards or emergency switchboards.

Note: When power is not supplied to ventilation fans due to a failure of distribution boards or wiring equipment downstream of main switchboards and emergency switchboards, total ventilation capacity is to not be less than 50%.

13.4.3 Ventilation Trunks

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

13.5 Machinery Spaces

13.5.1 Ventilation Systems for Machinery Spaces Containing Gas-fuelled Consumers

1 Ventilation systems for machinery spaces containing gas-fuelled consumers are to be independent of other ventilation systems.

2 Double wall pipes and ducts for machinery spaces containing gas-fuelled consumers are to be fitted with effective mechanical ventilation systems of an underpressure type. Such systems are to have a ventilation capacity of at least 30 *air changes per hour*. This, however, does not apply to double pipes in engine rooms that satisfy **9.7.1(1)**.

13.5.2 Ventilation Fans

The number and power of ventilation fans in double wall pipes and ducts of machinery spaces containing gas-fuelled consumers are to not to such that the capacity is not reduced by more than 50% of the total ventilation capacity even if the following fans cannot be used.

(1) Fans with separate circuits from main switchboards or emergency switchboards.

(2) Group of fans with common circuits from main switchboards or emergency switchboards.

Note: When power is not supplied to the ventilation fan due to a failure of distribution boards or wiring equipment downstream of main switchboards and emergency switchboards, total ventilation capacity is to not be less than 50%.

13.6 Fuel Preparation Rooms

13.6.1 Ventilation Systems for Fuel Preparation Rooms

Fuel preparation rooms are to be fitted with effective mechanical ventilation systems of an underpressure type, and such systems are to have a ventilation capacity of at least 30 *air changes per hour*.

13.6.2 Ventilation Fans

The number and power of ventilation fans in fuel preparation rooms are to not be such that the capacity is not reduced by more than 50% of the total ventilation capacity even if the following fans cannot be used.

(1) Fans with separate circuits from main switchboards or emergency switchboards.

(2) Group of fans with common circuits from main switchboards or emergency switchboards.

Note: When power is not supplied to ventilation fans due to a failure of distribution boards or wiring equipment downstream of main switchboards and emergency switchboards, total ventilation capacity is to not be less than 50%.

13.6.3 Operation of Ventilation Systems

Ventilation systems for fuel preparation rooms are to be in operation when pumps or compressors are working, and when fuel is in the fuel piping inside fuel preparation rooms.

13.7 Bunkering Stations

Bunkering stations that are not located on open decks are to be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If natural ventilation is not sufficient, the provision of mechanical ventilation is to be given special consideration.

13.8 Ducts and Double Pipes

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 systems of an extraction type, and such systems are to have ventilation capacity of at least 30 *air changes per hour*. This, however, does not apply to double pipes in engine rooms that satisfy **9.7.1(1)**.

13.8.2 Ventilation Fans

The number and power of ventilation fans in double wall piping and ducts are to not be such that capacity is reduced by more than 50% of total ventilation capacity even if the following fans cannot be used.

(1) Fans with separate circuits from main switchboards or emergency switchboards.

(2) Groups of fans with common circuits from main switchboards or emergency switchboards.

Note: When power is not supplied to ventilation fans due to failures of distribution boards or wiring equipment downstream of main switchboards and emergency switchboards, total ventilation capacity is to not be less than 50%.

13.8.3 Ventilation Systems for Double Piping and for Gas Valve Unit Spaces in Gas Safe Engine Rooms

Ventilation systems for double piping and for ducts are to be independent of other ventilation systems.

13.8.4 Ventilation Inlets

Ventilation inlets for double wall piping or ducts are to always be located in safe areas on open decks, taking into consideration any possible harm to the human body. Inlet openings are to be fitted with suitable wire mesh guards and protected from water ingress.

13.8.5 Ventilation Capacity

The ventilation capacity for pipe ducts or double wall piping may be below 30 *air changes per hour* if a flow velocity of a minimum of 3 *m/s* is ensured. Flow velocity is to be calculated for ducts with fuel pipes and other components installed.

13.9 Other

Double bottoms, cofferdams, duct keels, pipe tunnels, hold spaces and other spaces where fuel may accumulate are to be capable of being ventilated to ensure a safe environment when entry into them is necessary.

13.10 Increased Ventilation Requirements

Mechanical ventilation that immediately removes leaked ammonia from the spaces entered during normal operation is to be installed in spaces where ammonia-related equipment is installed. The specifications for mechanical ventilation are to be in accordance with the following **(1)** to **(3)**. However, other ammonia gas expulsion systems may be accepted by the Society.

(1) Increased ventilation systems are to have minimum capacities of at least 45 *air changes per hour* based upon the total volume of space.

(2) The ventilation capacity described in **(1)** above may include the ventilation capacity of mechanical ventilation in the enclosed or semi-enclosed spaces described in **Chapter 13**.

(3) When the gas concentration in the space exceeds 300 *ppm*, mechanical ventilation is to automatically start.

Note: Neither the IGC Code nor the IGF Code prohibit the emission of ammonia gas in an emergency, but there may be restrictions on the emission of leaked gas within sea areas which are expected to be the trade areas of the ship. Examples of such means are described below.

1 The following are means that suppress the release of ammonia into the atmosphere.

(1) Scrubbers

(a) Scrubbers are to be designed with an adequate processing capacity which restricts the gas concentrations at exhaust fans to well below 25 *ppm.*

(b) Maximum expected gas leakage amount is to be absorbed within 30 *minutes.*

(c) Pumps for scrubbers are to automatically start when gas concentrations in spaces exceeds 300 *ppm*.

(2) Water sprinkler systems in areas where fuel may leak.

(a) The quantity of sprinkled water is to be such that the leaked gas is satisfactorily absorbed.

(b) When gas concentrations in areas where fuel may leak exceed 300 *ppm*, pumps for sprinkling water are to automatically start automatically.

(c) Electrical equipment in areas where fuel may leak that is required to be operated in the event of leakage accidents, gas detection and alarm systems, and emergency lights are to be of certified safety types for use in flammable atmospheres.

2 The following are means that suppress the release of aqueous ammonia solution into the sea.

(1) Gas Absorption Water Tanks

(a) Gas absorption water tanks complying with the requirements given below are to be installed at positions lower than refrigerating machinery compartments so that the leaked liquid ammonia can be recovered quickly.

(b) Tanks are of a capacity sufficient to fully recover that maximum expected gas leakage amount.

(c) Automatic water supply systems are installed in tanks so that the fully filled condition of the tank is always maintained.

(d) Appropriate drain cups are provided to prevent reverse flow of the gas from the tank.

(e) Tank vent pipes are connected to the exhaust pipes of the ventilation systems specified in **Chapter 13**.

3 Overflow

In cases where overflow pipes from gas absorption water tanks need to be installed because the actual amount of aqueous ammonia solution exceeds the assumed amount so that it becomes difficult to store in the gas absorption water tank or in cases where overboard discharge is permitted by port administrations, overflow piping is to be arranged as follows.

(1) Overflow from the gas absorption water tanks is to be diluted or neutralized and then discharged overboard directly without leading the discharge pipes through accommodation spaces.

Chapter 14A SAFETY REQUIREMENTS FOR AMMONIA FLAMMABILITY (ELECTRICAL INSTALLATIONS)

14A.1 Goal

14A.1.1 General

The goal of this chapter is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14A.2 Functional Requirements

14A.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.

14A.2.2 Additional Requirements

Electrical generation and distribution systems (including their associated control systems) are to be designed so that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperatures within normal operating limits.

14A.3 General Requirements

14A.3.1 Electrical Installations

Electrical installations are to comply with applicable requirements in **Part H of the Rules**.

14A.3.2 Limits of Electrical Installations in Hazardous Areas

Electrical equipment or wiring is to not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

Note: Materials used for electrical equipment and cables to be installed in hazardous areas are to be selected in consideration of the physical properties of fuels.

14A.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 a certified safe type complying with **2.16, Part H of the Rules**.

14A.3.4 Failure Modes and Effects Analysis

Failure modes and the effects of a single failure in the electrical generation and distribution systems specified in **14.2** are to be analysed and documented to a standard recognized by the Society.

Note: Refer to IEC 60092 and IEC 60812.

14A.3.5 Lighting Systems

Lighting systems in hazardous areas are to be divided between at least two branch circuits. In addition, switches and protective devices are to interrupt all poles or phases and are to be located in non-hazardous areas.

14A.3.6 Bonding

Electrical equipment installed on board is to be such as to ensure safe bonding to the hull of the equipment itself.

14A.3.7 Low-liquid Level Alarms

Low-liquid level alarms and automatic shutdown arrangements are to be provided for motors in the event of low-low liquid levels, and automatic shutdown may be accomplished by sensing low pump discharge pressures, low motor currents, or low-liquid levels. Moreover, such shutdowns are to give audible and visual alarms on navigation bridges as well as in either continuously manned central control stations or onboard safety centres.

14A.3.8 Automatic Isolation of Motors

Submerged fuel pump motors and their supply cables may be fitted in fuel containment systems. Fuel pump motors are to be capable of being isolated from their electrical supply during gas-freeing operations.

14A.3.9 Electrical Installations in Specific Non-hazardous Areas

For non-hazardous spaces accessed from hazardous open decks in which the access is protected by airlocks, electrical equipment which is not of a certified safe type is to be de-energized upon loss of overpressure in the space.

14A.3.10 Electrical Equipment in Spaces Protected by Airlocks

Electrical equipment for propulsion, power generation, manoeuvering, anchoring and mooring, and emergency fire pumps that are located in spaces protected by airlocks are to be of a certified safe type.

Chapter 14B SAFETY REQUIREMENTS FOR AMMONIA TOXICITY

14B.1 Purpose

14B.1.1 General

The goal of this chapter is to minimize the effects of ammonia toxicity on ships and humans.

14B.2 Functional requirements

14B.2.1 General

This chapter is related to functional requirements in **3.2.2** to **3.2.6**, **3.2.12**, **3.2.13**, **3.2.14**, **3.2.16**, **3.2.18** and **3.2.19**.

14B.2.2 Isolation of ammonia

1 Toxic hazardous areas and non-toxic hazardous areas are to be properly separated.

2 Ammonia is to be prevented from inflowing into non-toxic hazardous areas.

3 Ammonia gas is to be emitted from a safe place.

14B2.2 Leakage control

Measures are to be taken to control leaked ammonia.

14B.2.3 Entering toxic hazardous locations

Measures are to be taken to avoid any exposure to ammonia upon entering toxic hazardous areas.

14B.2.4 Measures to mitigate the effects of ammonia exposure

Measures are to be taken to reduce human health hazards related to exposure to ammonia.

14B.2.5 Impact on ship operations

1 Arrangement of areas in which ship operations can be performed safely.

2 Prevent any obstruction to firefighting, evacuation, and other emergency operations due to the presence of ammonia.

14B.3 General Requirements

14B.3.1 Isolation of ship areas

1 Zone 0 and Zone 1 hazardous areas (enclosed spaces) are to not be adjacent to accommodation spaces, service spaces, electrical equipment rooms or control stations. The term “adjacent” means facial contact, linear contact, and point contact.

2 Zone 0 and Zone 1 hazardous areas (enclosed spaces) are to be gastight towards adjacent spaces.

3 Accommodation spaces, service spaces, electrical equipment rooms or control stations are to not be located in toxic hazardous areas on open decks as far as practicable. If this is not feasible, the boundaries of enclosed non-toxic hazardous areas are to be gastight and openings are to not be provided (including gastight doors.).

4 Access to area normally manned is to not be provided in toxic hazardous areas.

14B.3.2 Preventing the inflow of ammonia gas

1 In order to prevent ammonia gas from flowing into non-toxic hazardous areas, the following **(1)** to **(4)** are to be satisfied.

(1) Ventilation ducts in non-toxic hazardous areas are to be independent of ventilation ducts in toxic hazardous areas.

(2) Air intakes and exhausts designed and intended for use in non-toxic hazardous areas are to not be used in toxic hazardous areas.

(3) Entrances and exits of non-toxic hazardous areas are to not be provided in the toxic hazardous areas. If this is not feasible, the airlocks described in **5.10** are to be provided.

(4) Air intakes and exhausts of space normally manned spaces (such as accommodation spaces, service spaces, or control stations) are to be provided with equipment to close openings from the interior of the space in preparation for unexpected expansion of leaked gas.

14B.3.3 Emissions of ammonia gas

1 To be designed to minimize the emissions of ammonia gases into the air.

Note: The following events are generally considered to be emergency emissions:
・leaked ammonia emissions due to accidents, and
・emissions to avoid large-scale leaks due to fuel tank or fuel pipe damage.

2 Ammonia gas is to be discharged from a safe place in the atmosphere.

Note: Gas diffusion analysis is recommended to confirm the safety of arrangements of vent exhaust ports of fuel tanks and exhaust ports of leaked gas.

14B.3.4 Leakage control

1 A means for controlling ammonia leakage is to be provided. For this purpose, the following **(1)** to **(4)** are to be provided.

(1) Means of detecting leaked ammonia.

(2) Devices for shutting off leaked ammonia. Such devices are to automatically activate after detection of leaked ammonia.

(3) Means to prevent leaked ammonia from spreading if leakage is assumed to be on open decks.

(4) Devices for removing leaked ammonia from enclosed spaces.

2 Inlets and outlets for fuel preparation rooms are to be closed quickly to prevent the spread of gas in the case of ammonia leakage in fuel preparation rooms.

14B.3.5 Entering enclosed spaces

1 In Zone 0 toxic hazardous areas, ship personnel may enter after ammonia has been removed from the space by gas-freeing.

2 Under normal operating conditions, ship personnel are to not enter enclosed spaces which are Zone 1 and Zone 2 toxic hazardous areas. However, this does not apply when it is confirmed by fixed or portable equipment that the oxygen concentration in the atmosphere in the compartment concerned is sufficient and that it is not a toxic atmosphere.

3 Ship personnel entering toxic hazardous areas are required to be equipped with portable gas detectors. For this purpose, at least two portable gas detectors are to be provided on board with associated calibration equipment. Portable gas detectors required by the NK Rules for other gases which are also capable of detecting ammonia may be used to satisfy this requirement.

14B.3.6 Measures to mitigate the effects of ammonia exposure

1 Protective equipment

(1) Suitable protective equipment (including eye protection) to a recognized national or international standard is to be provided for the protection of ship personnel engaged in bunkering operations in consideration of the characteristics of ammonia.

(2) Personal protective and safety equipment required in this chapter is to be kept in suitable and clearly marked lockers in readily accessible locations.

2 First aid

(1) Stretchers

When fuel tanks are installed below deck, stretchers suitable for hoisting injured ship personnel from spaces below deck are to be kept in readily accessible locations.

(2) Medical First-aid Equipment

Ships are to be provided with onboard medical first-aid equipment (including oxygen resuscitation equipment) based on the provisions of the "Medical First Aid Guide (MFAG)" for ammonia.

3 Safety Equipment

(1) Number of pieces of safety equipment

At least three complete sets of safety equipment are to be provided in addition to the firefighter outfits required by **10.10**, **Part R of the Rules**. Each set is to provide adequate personal protection to permit entry and work in ammonia gas-filled spaces. Such equipment is to take into account the characteristics of ammonia.

(2) Composition of Safety Equipment

A complete set of safety equipment is to consist of the following.

(a) One self-contained positive pressure air-breathing apparatus incorporating a full-face mask (not using stored oxygen) that has a capacity of at least 1,200 *l* of free air.

(b) Boots and gloves to a recognized standard.

(c) A steel-cored rescue line with belt.

(d) An explosion-proof lamp.

(3) Supply of Spare Compressed Air

An adequate supply of compressed air is to be provided and is to consist of the following.

(a) At least one fully charged spare air bottle for each breathing apparatus required by **14B.3.6-1**.

(b) An air compressor of adequate capacity capable of continuous operation, suitable for the supply of high-pressure air of breathable quality.

(c) A charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by **14B.3.6-1**.

4 Additional Requirements for Personal Protection

(1) Respiratory Protection, etc. for Emergency Escape Purposes

Suitable respiratory and eye protection for emergency escape purposes is to be provided for each person on board, subject to the following (a) to (c).

(a) filter type respiratory protection is unacceptable,

(b) self-contained breathing apparatuses are to have at least a duration of service of 15 *minutes*, and

(c) emergency escape respiratory protection is to not be used for firefighting or cargo handling purposes and is to be marked to that effect.

5 Decontamination Showers and Eyewash Stations

Suitably marked decontamination showers and eyewash stations are to be available in safe locations outside of hazardous areas for ship personnel working on deck in consideration of the size and layout of the ship. Such showers and eyewashes are to be operable in all ambient conditions.

6 Lifeboats

Instead of the fully enclosed lifeboat described in **3.15, Chapter 3 of Part 3 of the Rules for Safety Equipment**, the air self-sufficient lifeboat stipulated in **3.17, Chapter 3 of Part 3 of the Rules for Safety Equipment** is to be installed. [Non-Japanese flagged] lifeboats are to be loaded with the self-contained air-sustaining boats described in **Reg 31.1.6, Chapter III of SOLAS Chapter III** and **4 8, Chapter IV of the LSA Code**.

7 Operating requirements

(1) Maintenance of Compressed Air Equipment

The compressed air equipment required by **-3** above is to be inspected at least once a month by a responsible officer and the results of such inspections are to be recorded in the ship' s log-book. In addition, such equipment is to be inspected and tested by a competent third party at least once a year.

14B.3.7 Effect on ship operations

1 Equipment related to ship operational control are to not be installed in toxic hazardous areas. Equipment related to ship operations includes but is not limited to the following:

(1) main propulsion systems,

(2) mains and emergency power systems,

(3) steering gear,

(4) fuel supply systems (limited to those that are manually operated for fuel changeover operations for vessels capable of changing over to oil fuel),

(5) oil fueling systems,

(6) anchoring and towing mooring systems operated by ship personnel (e.g. windlasses, chain stoppers, winches), and

(7) power sources for operating the equipment described in **(1)** to **(6)** above.

2 Access routes to areas related to ship navigation operations are to not be pass through toxic hazardous areas

14B.3.8 Additional requirements for fire safety

1 Firefighting equipment and fire extinguishing system operating control stations are to not be located in toxic hazardous areas, and access routes to such locations are to not pass through toxic hazardous areas as far as practical.

2 For the firefighting of ammonia fires in enclosed compartments, the firefighter outfits specified in **Chapter 23, Part R of the Rules**, are to be capable of fully covering and protecting the entire body from exposure to toxic ammonia.

Chapter 15 CONTROL, MONITORING AND SAFETY SYSTEMS

15.1 Goal

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 fuelled installations as covered in the other chapters of this part.

15.2 Functional Requirements

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 A single failure of the control, monitoring and safety systems of fuelled installations is to not lead to an unacceptable loss of power for propulsion and power generation.

2 Gas safety systems are to be arranged to automatically close down gas supply systems upon the system failures described in **Table 15.1** and upon other fault conditions which may develop too fast for manual intervention.

3 Safety functions are to be arranged in dedicated gas safety systems that are independent of gas control systems in order to avoid possible common cause failures. This includes power supplies, and input and output signals.

4 Safety systems (including associated field instrumentation) are to be arranged to avoid spurious shutdowns (e.g. shutdowns caused by faulty gas detectors or wire breaks in sensor loops).

5 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.

6 Control, monitoring and safety systems are to be appropriately provided in consideration of the physical properties of the fuel to ensure operational safety and reliability.

15.3 General

15.3.1 Reading of Parameters

Suitable instrumentation devices are to be fitted to allow local and remote reading of essential parameters to ensure the safe management of all fuelled installations (including bunkering installations).

15.3.2 Level Indicators and Temperature Sensors in Bilge Wells

Bilge wells in tank connection spaces of independent liquefied gas storage tanks are to be provided with level indicators and temperature sensors. Alarms are to be given at high levels in bilge wells, and low temperature indications are to activate safety systems. Temperature sensors, however, may be provided when the temperatures in tank connection spaces is low due to ammonia leakage.

15.3.3 Monitoring Systems for Non-permanently Installed Tanks

Monitoring systems similar to the ones provided for permanently installed tanks are to be provided for non-permanently installed tanks.

15.4 Bunkering and Liquefied Gas Fuel Tank Monitoring

15.4.1 Level Indicators for Liquefied Gas Fuel Tanks

1 Liquefied gas fuel tanks are to be fitted with liquid level gauges so arranged to ensure a level reading is always obtainable whenever the liquefied gas fuel tank is operational. Such gauges are 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 so arranged 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 radioisotopes or ultrasonic devices.

15.4.2 Overflow Control

1 Liquefied gas fuel tanks are to be fitted with high liquid level alarms operating independently of other liquid level indicators that give continuous audible and visual warnings on navigation bridges as well as in either continuously manned central control stations or onboard safety centres when activated.

2 Additional sensors operating independently of the high liquid level alarms are automatically to actuate shutoff valves in a manner that will both avoid excessive liquid pressure in bunkering lines and prevent liquefied gas fuel tanks from becoming liquid full.

3 Pumps transferring fuel between fuel tanks are to be shut down when the high-level alarms in the fuel tanks being supplied with ammonia are activated.

4 The positions of the sensors in liquefied gas fuel tanks are 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 levels in the liquefied gas fuel tanks to their alarm points.

5 The elements of high level and overfill alarms (including electrical circuits and sensors) are to be capable of being functionally tested. Systems are to be tested prior to fuel operations.

6 Where arrangements are provided for overriding overflow control systems, they are to be such that inadvertent operation is prevented. Moreover, when overriding such systems, continuous visual indications are to be given on navigation bridges as well as in either continuously manned central control stations or onboard safety centres.

15.4.3 Pressure Reading Gauges for Vapour Spaces of Tanks

Vapour spaces of liquefied gas fuel tanks are to be provided with direct reading gauges. Moreover, indirect indications are to be given on navigation bridges as well as in either continuously manned central control stations or onboard safety centres.

15.4.4 Marking of Permittable Pressure in Tanks

Pressure indicators are to be clearly marked with the highest and lowest pressure permitted in liquefied gas fuel tanks.

15.4.5 Pressure Alarms

High-pressure alarms and, if vacuum protection is required, low-pressure alarms are to be given on navigation bridges as well as in either continuously manned central control stations or onboard safety centres. 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

Fuel pump discharge lines, and liquid and vapour fuel manifolds are to be provided with at least one local pressure indicator.

15.4.7 Pressure Indicators for Manifolds

Local-reading manifold pressure indicators are to be provided to indicate the pressure between ship manifold valves and hose connections to the shore.

15.4.8 Pressure Indicators for Fuel Storage Hold Spaces and Interbarrier Spaces

Fuel storage hold spaces and interbarrier spaces without open connections to the atmosphere are to be provided with pressure indicators.

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, low-liquid level alarms are to be arranged and motors are to automatically shut down in the event of low-low liquid levels. Automatic shutdown may be accomplished by sensing low pump discharge pressures, low motor currents, or low-liquid levels. Moreover, such shutdowns are to give audible and visual alarms on navigation bridges as well as in either continuously manned central control stations or onboard safety centres.

15.4.11 Fuel Temperature Measuring Positions

Except for type *C* independent tanks supplied with vacuum insulation systems and pressure build-up fuel discharge units, fuel tanks are to be provided with devices to measure and indicate the fuel temperature for at least three locations: the bottom of the tank, the middle of the tank, and the top of the tank below the highest allowable liquid level.

15.5 Bunkering Control

15.5.1 Remote Monitoring and Control

Remote bunkering control is to be possible from safe locations away from bunkering stations. At such locations, the monitoring, control and indication specified in the following **(1)** to **(3)** are to be capable of being carried out.

(1) Monitoring of 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 **11.6-6**.

(3) Indication of overfill alarms and automatic shutdown.

15.5.2 Stopping Alarms for Duct Ventilation Systems

If the ventilation in the ducting enclosing the bunkering lines stops, audible and visual alarms are to be given at bunkering control locations.

15.5.3 Gas Detection Alarms for Duct Ventilation Systems

If gas is detected in the ducting around bunkering lines, audible and visual alarms are to be provided at bunkering control locations, and emergency shutdown is to be possible.

15.6 Gas Compressor Monitoring

15.6.1 Gas Compressors

Gas compressors are to be fitted with audible and visual alarms both on navigation bridges and in engine control rooms. As a minimum, such alarms are to indicate low gas input pressures, low gas output pressures, high gas output pressures and compressor operations.

15.6.2 Shaft Glands and Bearings

Temperature monitoring for bulkhead shaft glands and bearings are to be provided and automatically give continuous audible and visual alarms on navigation bridges and in continuously manned central control stations.

15.7 Gas Engine Monitoring

15.7.1 Indicators

In addition to the instrumentation required in accordance with **Part D of the Rules**, indicators for the following are to be fitted on navigation bridges, in engine control rooms and at equipment operating locations:

(1) Engine operations in the case of gas-only engines.

(2) Engine operations and operating modes in the case of dual fuel engines.

15.8 Gas Detection

15.8.1 Gas Detector Arrangements

Permanently installed gas detectors are to be fitted in the following:

(1) tank connection spaces;

(2) all ducts around fuel pipes;

(3) machinery spaces containing gas piping, gas-fuelled equipment or gas-fuelled consumers;

(4) 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 vapour may accumulate (including interbarrier spaces and fuel storage hold spaces of independent tanks other than type *C*);

(7) airlocks;

(8) expansion tanks of systems that exchange heat with fuel;

(9) motor rooms associated with the fuel systems;

(10) at ventilation inlets to accommodation and machinery spaces (if required based on the risk assessment required in **4.2**), and

(11) enclosed and semi-enclosed bunkering stations.

15.8.2 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.

15.8.3 Confirmation og Gas Detector Arrangements

Gas detectors are to be located where gas may accumulate and in ventilation outlets. Gas dispersal analysis or a physical smoke test is to be used to find the best arrangement.

15.8.4 Gas Detection Equipment Design, Installation and Testing

Gas detection equipment is to be designed, installed and tested in accordance with a standard recognized by the Society.

15.8.5 Alarm and Safety System Set Points

1 Audible and visible alarms are to be activated at gas vapour concentrations of 25 *ppm*.

2 Safety systems are to be activated when 300 *ppm* is detected at two detectors (see **Note 1** in **Table 15.1**).

15.8.6 Alarm Locations

Audible and visible alarms for gas detection equipment are to be located at the entrances of spaces where the detectors are installed as well as on navigation bridges or in continuously manned central control stations.

15.8.7 Gas Detection Capability

Gas detection required by this **15.8** is to be continuous without delay.

15.8.8 Potable Gas Detectors

In the application of **14B.3.5**, at least two portable gas detectors complying with a standard recognized by Society are to be provided in order to measure the content of ammonia.

15.9 Fire Detection

15.9.1 Fire Detection

1 Fixed fire detection and fire alarm systems complying with **Chapter 29**, **Part R of the Rules** are to be provided for machinery spaces containing gas-fuelled engines, fuel preparation rooms containing equipment considered to be ignition sources, enclosed or semi-enclosed bunkering stations, and all other rooms of the fuel gas system where fire cannot be excluded.

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

3 Required safety actions for fire detection in machinery spaces containing fuelled engines are given in **Table 15.1** below.

15.10 Ventilation

15.10.1 Alarms

Any loss of the required ventilating capacity is to give audible and visual alarms on navigation bridges as well as in either continuously manned central control stations or onboard safety centres.

15.11 Fuel Supply System Safety Functions

15.11.1 Automatic Valve Activation

If the fuel supply is shut off due to activation of an automatic valve, the fuel supply is to not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect is to be placed at the operating stations for the shutoff valves of fuel supply lines.

15.11.2 Fuel Leaks

If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply is to not be operated until the leak has been found and dealt with. Instructions to this effect are to be placed at prominent positions in machinery spaces.

15.11.3 Heavy Lifting

Caution placards or signboards are to be permanently fitted in machinery spaces containing gas-fuelled engines stating that heavy lifting, implying danger of damage to fuel pipes, is to not 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 bridges,

(2) cargo control rooms,

(3) onboard safety centres,

(4) engine control rooms,

(5) fire control stations, and

(6) adjacent to the exits of fuel preparation rooms.

Gas compressors are also to be arranged for manual local emergency stop.

Table 15.1 Monitoring of Gas Supply System to Engines

Parameter	Alarm	Automatic shutdown of tank valve[6]	Automatic shutdown of gas supply to machinery spaces containing gas-fuelled engines	Automatic start-up of mechanical ventilation (**13.3.1-5**) or increased ventilation requirements (**13.10**)	Comments
Gas detection in tank connection spaces at 25 *ppm*	X				
Gas detection by two detectors[1] in tank connection spaces at 300 *ppm*	X	X		X	
Fire detection in fuel preparation rooms	X				
Bilge well high level in tank connection spaces	X				
Bilge well low temperature in tank connection spaces	X	X			
Gas detection in secondary spaces between tanks and machinery spaces containing gas-fuelled engines at 25 *ppm*.	X				
Gas detection by two detectors[1] in secondary spaces between tanks and machinery spaces containing gas-fuelled engines at 300 *ppm*	X	X [2]		X	
Gas detection in fuel preparation rooms at 25 *ppm*	X				
Gas detection by two detectors[1] in fuel preparation rooms at 300 *ppm*	X	X [2]		X	
Gas detection in secondary spaces inside machinery spaces containing gas-fuelled engines at 25 *ppm*	X				If double pipes fitted in machinery spaces containing gas-fuelled engines
Gas detection by two detectors[1] in secondary spaces inside machinery spaces containing gas-fuelled engines at 300 *ppm*	X		X [3]	X	If double pipes fitted in machinery spaces containing gas-fuelled engines
Loss of ventilation in ducts between tanks and machinery spaces containing gas-fuelled engines	X		X [2]		
Loss of ventilation in secondary spaces inside	X		X [3]		If double pipe fitted in

machinery spaces containing gas-fuelled engines[5)]					machinery space containing gas-fuelled engines
Fire detection in machinery spaces containing gas-fuelled engines	X				
Abnormal gas pressure in gas supply pipes	X				
Failure of valve control actuating media	X		X [4)]		Time delayed as found necessary
Automatic shutdown of engines (engine failure)	X		X [4)]		
Manually activated emergency shutdown of engines	X		X		
Loss of electric power supplies		X	X		

1) Two independent gas detectors located close to each other are required for redundancy reasons; however, the installation of a single gas detector of a self-monitoring type may be permitted.
2) For tanks supplying ammonia gas to more than one engine with different supply pipes that are completely separated and fitted in separate ducts for which the master valves are fitted on the outsides of ducts, 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 with different supply pipes that are completely separated and fitted in separate ducts for which the master valves are fitted on the outsides of ducts and on the outsides of machinery spaces 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 are to close.
5) For ducts protected by inert gas (see **9.6.1(1)**), the loss of inert gas overpressure is to lead to the same actions as given in this table.
6) The valves referred to in **9.4.1**.

Chapter 16 MANUFACTURE, WORKMANSHIP AND TESTING

16.1 General

16.1.1 General

1 Manufacture, testing, inspection and documentation are to be in accordance with the requirements of this chapter in addition to requirements in other relevant chapters.

2 Where post-weld heat treatment is specified or required, base material properties are to be determined in the heat-treated condition in accordance with the applicable tables of **Chapter 7**, and 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 requirements may be modified at the discretion of the Society.

16.2 General Test Regulations and Specifications

16.2.1 Tensile Tests

1 Tensile testing is to be carried out in accordance with the requirements of **Chapter 2, Part K of the Rules** for base materials and **Chapter 3, Part M of the Rules** 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 Tests

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 of the Rules**. The testing and regulations for specimens smaller than 5.0 *mm* in size are to be as deemed appropriate by the Society, and minimum average values for sub-sized specimens are to be in accordance with **Table 16.1**.

Table 16.1

Charpy *V*-notch specimen size	Minimum average energy of three specimens

10 *mm*×10 *mm*	*KV*
10 *mm*×7.5 *mm*	5/6*KV*
10 *mm*×5.0 *mm*	2/3*KV*

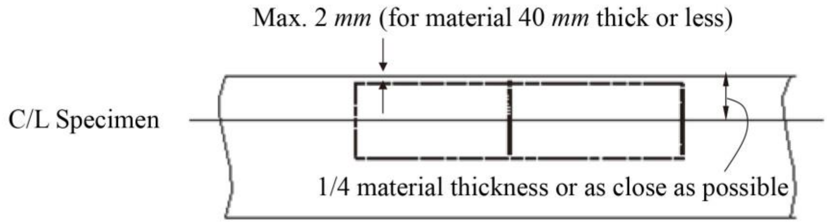
where

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 that it is not less than 70% of that value.

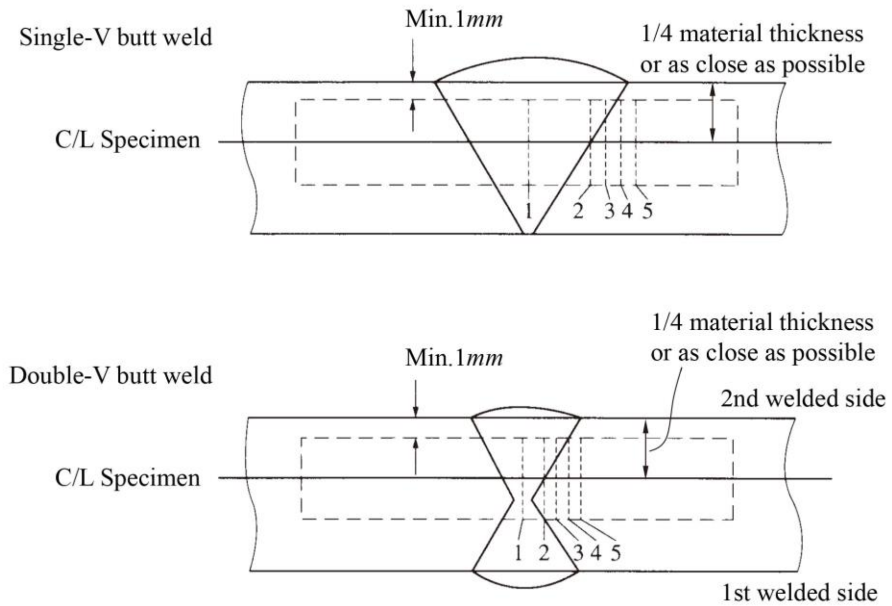
2 For base materials, the largest size Charpy *V*-notch impact test specimens possible for the material thickness are to be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in **Fig. 16.1**.

Fig. 16.1 Orientation of Base Material Test Specimen



3 For weld test specimens, 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, double-*V* butt weld 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. 16.2**): on the centreline of the weld, on the fusion line and at locations 1 *mm*, 3 *mm* and 5 *mm* from the fusion line.

Fig. 16.2 Orientation of Weld Test Specimen



Notch locations in **Fig. 16.2** are to be as follows:

1. on the centreline of the weld,
2. on the fusion line,
3. in the heat-affected zone (*HAZ*), 1 *mm* from the fusion line,
4. in the HAZ, 3 *mm* from the fusion line, and
5. in the HAZ, 5 *mm* from the fusion line.

4 If the average value of the three initial Charpy *V*-notch impact test specimens fails to meet the stated regulations, the value for more than one specimen is below the required average value, or 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 Tests

1 Bend tests 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 of the Rules**.

2 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

Macro tests, micro tests and hardness tests may also be required by the Society, and are to be carried out as deemed appropriate by the Society.

16.3 Welding of Metallic Materials and Non-destructive Testing for Fuel Containment Systems

16.3.1 General

This **16.3.1** applies to primary and secondary barriers only; this includes inner hulls which form secondary barriers. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and austenitic stainless steels, but such tests may also be adopted for other materials. Impact testing of austenitic stainless steel and aluminium alloy weldments may be omitted at the discretion of the Society, and tests other than those specified in section may be also be required by the Society.

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 of the Rules**. Deposited weld metal tests and butt weld tests are 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 of the Rules**. The chemical composition of the deposited weld metal is to be recorded for reference purposes.

16.3.3 Welding Procedure Tests for Fuel Tanks and Process Pressure Vessels

1 Welding procedure tests for fuel tanks and process pressure vessels in accordance with the following **-2** to **-5** are required for butt welds.

2 The test assemblies are to be representative of the following:

(1) each base material,

(2) each type of consumable and welding process, and

(3) each welding position.

3 For butt welds in plates, 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 of the Rules** and **Chapter 4, Part M of the Rules**. Non-destructive tests are to be in accordance with the requirements in **Chapter 11, Part D of the Rules** and **Chapter 4**, **Part M of the Rules**.

4 The following welding procedure tests for fuel tanks and process pressure vessels are to be done in accordance with **16.2** with specimens taken from each test assembly:

(1) Cross-weld tensile tests.

(2) Longitudinal all-weld testing where required by the requirements in **Chapter 4, Part M of the Rules**.

(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. 16.2**):

(a) the centreline of the weld,

(b) the 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) Macro tests, micro tests and hardness tests may also be required.

5 Each test is to satisfy the following.

(1) Tensile tests: Cross-weld tensile strength is to not 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 reference purposes.

(2) Bend tests: No fracture is acceptable after a 180-degree bend over a former of a diameter four *times* the thickness of the test pieces.

(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. Among the results of weld metal impact tests, minimum average energy value (*KV*) is to be no less than 27*J*. The weld metal requirements 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; in addition, the minimum average energy value (*KV*) for sub-size specimens 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 of the Rules** and **Chapter 4, Part M of the Rules**. 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 of the Rules**.

16.3.4 Welding Procedure Tests for Piping

Welding procedure tests for piping are to be carried out and be similar to those specified for fuel tanks in **16.3.3**.

16.3.5 Production Weld Tests

1 For fuel tanks and process pressure vessels (except membrane tanks), production weld tests are to generally be performed for approximately each 50 *m* of butt-welding 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 Society approval. Tests other than those specified in **-2** to **-5** may be required for fuel tanks or secondary barriers.

2 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. Such tests are to be made for each 50 *m* of welding. Charpy *V*-notch impact tests are to be carried out using 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** above. Tensile tests are to be in accordance with **16.3.3-5**.

4 The quality assurance/quality control (QA/QC) program is to ensure the continued conformity of production welds as defined in material manufacturer quality manuals (QM).

5 Test requirements 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, in principle, to be used to detect internal defects. However, approved ultrasonic test procedures in lieu of radiographic testing may be conducted when approved by the Society, provided that additional supplementary radiographic testing at Society selected locations is carried out to verify the results. Radiographic and ultrasonic testing records are to be retained.

2 For type *A* independent tanks with design temperatures below −20°C and type *B* independent tanks (regardless of temperature), 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 to not 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 described in **-1** above 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

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 of the Rules**. 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 for Tanks

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 gastightness 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 on a per case basis 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 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 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 so 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 so 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 fuel containment system. Testing conditions considered in the analytical and physical model are to represent the most extreme service conditions the fuel containment system will be likely to encounter over its lifetime. 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-type 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 fuel containment system.

(3) Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

16.6 Welding, Post-weld Heat Treatment and Non-destructive Testing

16.6.1 General

Welding 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, the tests following **(1)** to **(4)** are to be carried out as necessary to prove that the welding was performed correctly and accordance with the requirements in this chapter.

(1) 100% radiographic testing or ultrasonic testing of butt-welded joints for piping systems with any of the following **(a)** to **(e)**:

- (a) design temperatures colder than −10°C,
- (b) design pressure greater than 1.0 *MPa*,
- (c) gas supply pipes in *ESD* protected machinery spaces,
- (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 testing may be acceptable but such reductions are to be less than 10% of each joint. If defects are revealed, the extent of examination is to be increased to 100% and is to include the 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) Radiographic or ultrasonic testing requirements may be reduced to 10% for butt-welded joints in the outer pipes of double-walled fuel piping.

(4) For butt-welded joints of pipes not covered by **(1)** to **(3)** above, spot radiographic or ultrasonic tests or other non-destructive tests are to be carried out to the satisfaction of the Society according to the intended use, location of use and materials used. In general, at least 10% of butt-welded joints of pipes are to be subjected to radiographic or ultrasonic testing.

16.7 Testing for Pipings

16.7.1 Type Testing of Piping Components

Each type of piping component intended to be used at a working temperature below −55°C is to be subject to the following **(1)** to **(4)** type tests.

(1) Each size and type of valve is to be subjected to seat tightness testing at intervals over the full range of operating pressures and temperatures up to the rated design pressure of the valve. Allowable leakage rates are to be in accordance with standards recognized by the Society. Satisfactory valve operation is to be verified during testing.

(2) The flow or capacity is to be certified to standards 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 their design pressures.

(4) For emergency shutdown valves made of materials having melting temperatures lower than 925°C, type testing is to include fire tests to standards recognized by the Society.

16.7.2 Expansion Bellow Joints

The following **(1)** to **(4)** type tests are to be performed on each type of expansion bellow joint used for fuel piping installed outside of fuel tanks in accordance with **7.3.6-4(3)** as well as for fuel piping installed within fuel tanks in cases where required by the Society.

(1) Bellows elements (not pre-compressed but axially restrained) are to be pressure tested at not less than five times their design pressure to verify there is no bursting. The duration of the test is to not be less than five minutes.

(2) Pressure tests are to be performed on complete expansion joints (i.e. joints with all accessories such as flanges, stays and articulations attached) at their minimum design temperature and twice their design pressure at the extreme displacement conditions recommended by manufacturers to verify there is no permanent deformation.

(3) Cyclic tests (thermal movements) are to be performed on complete expansion joints to verify that the joint is capable of withstanding at least as many cycles under the pressure, temperature, axial movement, rotational movement and transverse movement conditions 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) Cyclic fatigue tests (ship deformation, ship accelerations and pipe vibrations) are to be performed on complete expansion joints (without internal pressure) by simulating the bellows movement corresponding to the compensated pipe length for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when ship deformation loads are actually experienced due to piping arrangements .

16.7.3 System Testing

1 This **16.7.3**, in principle, applies to the testing of fuel piping installed within and outside of fuel tanks. The application of these requirements, to piping installed within fuel tanks and open-ended piping, however, may be relaxed when deemed acceptable by the Society.

2 After assembly, all fuel piping is to be subjected to strength tests using suitable fluids. Test pressures are to be at least 1.5 *times* design pressure for liquid lines and 1.5 *times* maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, such tests may be conducted prior to installation on board ship. In addition, joints welded on board are to be tested to at least 1.5 *times* their design pressure.

3 After assembly on board, fuel piping systems are to be subjected to leak tests using air or some other suitable medium to a pressure in accordance with the leak detection method applied.

4 Outer pipes and ducts of double wall fuel piping systems are also to be pressure tested to show that they can withstand the expected maximum pressure generated 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 no later than the first bunkering operation in accordance with standards deemed recognized by 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 is to be available on board, and the closing time is to be verifiable and repeatable.

7 The closing times of the valves referred to in **8.5.8** and **15.4.2-2** (i.e. time from shutdown signal initiation to complete valve closure) are to not be greater than the following.

$$\frac{3600U}{BR} \text{ (second)}$$

where

U : ullage volume at operating signal level (m^3)

BR: maximum bunkering rate agreed between ship and shore facility (m^3/h), or

5 seconds, whichever is less

Bunkering rates are to be adjusted to limit surge pressure on valve closure to acceptable levels in consideration of the bunkering hose or arm and relevant ship and shore piping systems.

8 The Society may require testing of fuel supply systems to establish compliance with expected operating conditions.

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 so as to minimize risks to ship personnel, ships and the environment that are consistent with common practice for conventional oil-fuelled ships 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 the *IGF Code* or national regulations incorporating the provisions of the *IGF Code* as well as a copy of the Guidelines are to be provided on board every ship covered by this chapter.

2 Maintenance procedures and information for all fuel related installations are to be available on board.

3 Ships are to be provided with operational procedures (including suitably detailed fuel handling manuals) so that trained ship personnel can safely operate fuel bunkering, storage and transfer systems.

4 Ships are to be provided with suitable emergency procedures.

17.3 Fuel Handling Manuals and Notices

17.3.1 Fuel Handling Manuals

The fuel handling manuals required by **17.2.2-3** are to include but are not limited to the following **(1)** to **(9)**.

(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 (including the operation and maintenance of firefighting systems and use of extinguishing agents).

(6) Special equipment needed for the safe handling of fuels with special characteristics.

(7) Fixed and portable gas detection system operation and maintenance.

(8) Emergency shutdown and emergency release systems (where fitted).

(9) Descriptions of procedural actions to be taken in emergency situations (such as leakage, fire or potential fuel stratification resulting in rollover).

17.3.2 Notices

Fuel system schematic or piping and instrumentation diagrams (P&ID) are to be reproduced and permanently displayed on placards mounted in ship bunker control stations and at bunkering stations.

17.4 Maintenance and Repair Procedures

17.4.1 General

1 Maintenance and repair procedures are to give consideration to 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

This **17.5** is 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 ship personnel responsible for ship 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 Electrical Installation Inspection and Maintenance

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 Operations

1 Responsibility

(1) Before any bunkering operations commence, ship master of the receiving ship (or their representatives) and the representatives of bunkering sources (i.e. the person(s)-in-charge or PIC) are to do following **(a)** to **(c)**.

   (a) Agree (in writing) to the transfer procedure in writing; this includes cooling down and gassing up (if necessary), the maximum transfer rate at all stages and the volume to be transferred.

   (b) Agree (in writing) to the actions to be taken in emergencies.

   (c) Complete and sign bunker safety checklists.

(2) Upon completion of bunkering operations, the ship PIC is to receive and sign a Bunker Delivery Note for the fuel delivered that was completed and signed by the bunkering source PIC.

(3) Dissolved Oxygen Content

In order to minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2.5 *ppmw*/*w*. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature *T* in the **Table 7.5**. (Refer to **7.4.3.7-1**)

(4) Precautions when using carbon manganese steel

(a) Ship masters are to be provided with documentation confirming **7.3.1(4)**.

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 bunker safety checklists:

(a) all communications methods (including ship-shore links (*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 a mutually agreed upon and completed bunkering safety checklist signed by both PICs.

3 Ship bunkering source communications

(1) Communication is to be maintained between ship PICs and bunkering source PICs at all times during bunkering operations. In the event that such communication cannot be maintained, bunkering is to stop and not resume until communication is restored.

(2) Communication devices used in bunkering are to comply with standards for such devices recognized by the Society.

(3) PICs are to have direct and immediate communication with all ship personnel involved in bunkering operations.

(4) Ship-shore links (SSL) or equivalent means to bunkering sources provided for automatic ESD communication are to be compatible with receiving ship and bunkering source ESD systems.

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 Transfer conditions

(1) Warning signs are to be posted at access points to bunkering areas listing the fire safety precautions during fuel transfer.

(2) During transfer operations, ship personnel in bunkering manifold areas is to be limited to essential persons only.

All ship personnel engaged in duties or working in the vicinity of bunkering operations are to wear appropriate personal protective equipment (PPE). Bunkering operations are to cease if required transfer conditions are not maintained and are to not resume until all required conditions are met.

(3) Where bunkering is to take place via the installation of portable tanks, procedures are to provide a level of safety equivalent to that provided for 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 fuel systems.

(4) For tanks not permanently installed on ships, the connection of all necessary tank systems (piping, controls, safety system, relief system, etc.) to ship fuel systems is to be considered to be 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 voyage or manoeuvring in ports is not permitted.

17.5.5 Enclosed Space Entry

1 Under normal operational circumstances, ship personnel are to not enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate unless the gas content of the atmosphere in such spaces is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of explosive atmospheres.

2 Ship personnel entering any spaces designated as hazardous areas are to not introduce any potential source of ignition into said space unless it has been certified gas-free and maintained in that condition.

17.5.6 Fuel System Inerting and Purging

1 The primary objective in the inerting and purging of fuel systems is to prevent the formation of combustible atmospheres 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 tanks containing gas atmospheres, and that gas is not introduced into air contained in enclosures or spaces adjacent to fuel systems.

3 Liquid ammonia is never to be sprayed into tanks containing air as there is a risk of creating a static electrical charge which could cause ignition.

4 To minimize the risk of stress corrosion cracking occurring when ammonia is carried at a temperature above −20°C (vapour pressure 0.19 MPa), the oxygen contents of vapour spaces in pressure vessels and in pipelines made of carbon-manganese steel (and other steels which require special consideration) are to be reduced to the minimum level practicable before liquid ammonia is introduced.

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 necessary approvals have been obtained.

17.5.8 Personal Protective Equipment

Proper personal protective equipment is to be worn according to the type of work with consideration being given to ammonia toxicity. Risk assessments of types of work are to be carried out to determine whether such equipment is necessary.

Part C-2 Guidelines for the Safety of Liquefied Gas Carriers Using Ammonia as Fuel

Chapter 18 USE OF CARGO AS FUEL

18.1 General

18.1.1 General Requirements

This chapter applies to liquefied gas carriers using ammonia as fuel subject to the conditions specified in the following **(1)** and **(2)**. For liquefied gas carriers that use ammonia as fuel, an alternative design to **Chapter 16, Part N of the Rules** is to be implemented, and the equivalence of said alternative design is to be demonstrated as specified in **1.1.2, Part N of the Rules** as well as be approved by Administrations.

(1) Liquefied gas carriers using ammonia as fuel that comply with the requirements of **Part N of the Rule**s; or

(2) Liquefied gas carriers using ammonia as fuel, provided that the fuel storage and distribution systems design and arrangements for LPG fuels comply with the requirements of **Part N of the Rules**.

Note: Application of **Part N of the Rules**

1 For ships described in **16.1.1(1), Part N of the Rules**, fuel tanks and fuel piping (including bunkering pipes) are subject to the requirements for cargo storage equipment and cargo pipes.

2 For ships described in **16.1.1(2), Part N of the Rules**, fuel tanks and fuel piping (including bunkering pipes) are subject to the requirements for cargo storage equipment and cargo pipes.

18.1.2 Definitions

In addition to the definitions specified in **1.1.4, Part N of the Rules** and **Part C-1**, the definitions of terms in this chapter are as defined in the following **(1)** to **(6)**.

1 *Fuel* as described in **Part C-2** is treated as cargo in the cargo area and is to comply with **Part N of the Rules** (excluding **Chapter 16**) in addition to **Part C-1**.

2 *Fuel conditioning system* means all associated storage tanks and equipment for processing ammonia as fuel (such as heat exchangers, compressors, evaporators and filters).

3 *Fuel pipes* means a bunkering pipes and fuel supply pipes. However, bunkering pipes are not included when applying **18.4.3**.

4 *Cargo machinery spaces* means any space containing pumps, compressors, vapourisers, heat exchanger or pressure vessels for fuel preparation purposes.

5 *FVU room* means spaces where only the piping and valves used for fuel supply are installed outside of cargo areas.

6 For the purpose of **18.9**, *toxic hazardous area* means spaces where ammonia is present and where gas generated from the same place may cause human health hazard in consideration of the ammonia toxicity. (Refer to **18.9**)

18.1.3 Risk Assessment

Risk assessments are to be conducted to ensure that risks arising from the use of ammonia fuels affecting ship personnel, the environment, and ship structural strength or integrity are addressed. For risk assessments, 18.4 below applies.

18.2 Use of Cargo Vapour as Fuel

This **18.2** addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units and gas turbines.

18.2.1 Fuel Systems Supplying Ammonia

For vapourised ammonia, fuel supply systems are to comply with **18.**4.1, **18.**4.2 and **18.**4.3.

18.2.2 Fuel Consumers

For vapourised ammonia, gas consumers are to exhibit no visible flame and are to maintain uptake exhaust temperatures that do not exceed the spontaneous combustion temperature of ammonia.

Note: The spontaneous combustion temperature of ammonia is 630°C.

18.2.3 Spaces Containing Fuel Conditioning Systems

Spaces containing equipment related to adjusting cargo used as fuel (heaters, compressors, evaporators, filters, etc.) are considered to be the cargo machinery rooms described in **1.4, Part N of the Rules** and are subject to the requirements of **Part N of the Rules**. However, FVU rooms containing only piping and valves used for fuel supply may be located outside of cargo areas. In such cases if the only access to the FVU room is from the engine room via an airlock, the FVU room and the airlock are to be treated as part of the engine room.

18.3 Spaces Containing Fuel Consumers

18.3.1 Mechanical Ventilation System

Spaces containing gas consumers are to be fitted with mechanical ventilation systems that are arranged so as to avoid areas where fuel may accumulate in consideration of vapour density, potential ignition sources and toxicity. Such ventilation systems are to be separated from those serving other spaces.

18.3.2 Gas Detectors

Gas detectors are to be fitted in spaces where there are considered to be risks of fuel leakage. In addition, gas detectors are to comply with **18.4.8**.

18.3.3 Electrical Equipment Located in Double Wall Pipes and Ducts

Electrical equipment located in the double wall pipes and ducts specified in **18.4.3** is to comply with the requirements of **Chapter 10, Part N of the Rules**.

18.3.4 Vents and Bleed Lines

All vents and bleed lines that may contain or be contaminated by gas fuel are to be routed to the vent systems described in **8.2.10 and 8.2.11, Part N of the Rules**.

18.4 Fuel Supply

18.4.1 General

1 This **18.4** applies to gas fuel supply piping installed outside of cargo areas. Even if protected by secondary enclosures, such fuel piping is to not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. In addition, the routing of such piping is to take into account potential hazards due to mechanical damage, particularly in areas such as stores or machinery handling areas.

Note: If secondary enclosures are protected by gastight enclosures, fuel pipes may pass through accommodation spaces, service spaces, electrical equipment rooms, and control stations.

2 Arrangements are to be made for inerting and gas-freeing those portions of gas fuel piping systems located in machinery spaces.

3 Fuel supply systems are to be designed to prevent phase changes in supply systems up to fuel consumers.

4 Where fuel is intended to be used in the gaseous state and has a dew point higher than ambient temperature at the maximum expected pressure at the consumer inlet, the fuel is to be sufficiently heated, and the fuel lines are to be properly heat traced.

5 Where fuel is intended to be used as liquid fuel for fuel consumers, fuel supply pressure is to be sufficient to maintain the liquid state.

6 Materials are to be selected in consideration of the corrosiveness of the fuel according to the relevant environment condition.

7 Fuel piping is to be designed to enable drainage to be led to suitable tanks under list and trim conditions during voyage.

18.4.2 Gas Leak Detection

Continuous monitoring and alarms are to be provided to indicate leaks in the piping systems in secondary enclosures and shut down relevant gas fuel supplies.

18.4.3 Protection of Fuel Supply Pipes

1 Fuel piping installed outside of cargo areas are to be protected by secondary enclosures that satisfy either of the following conditions.

(1) The piping is 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 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 fuel valve and the engine is automatically purged with inert gas when the master fuel valve is closed; or

(2) The piping is installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour and is arranged to maintain a pressure less than atmospheric pressure. The mechanical ventilation is in accordance with **Chapter 12**, **Part N of the Rules**, as applicable. The ventilation is capable of being automatically operated when fuel leaks are detected by the equipment described in **18.4.8** and the master gas fuel valve (as required by **18.**4.6), automatically closes if the required air flow is not established and maintained by the exhaust ventilation system. For inlet or outlet arrangements, **18.4.7** applies.

2 Fuel delivery lines between high-pressure fuel pumps or compressors and fuel consumers are to be protected with double-walled piping systems capable of containing high-pressure line failures in consideration of the effects of both pressure and low temperature.

3 In accordance with **16.4.6**, pipes or trunks are to be capable of containing a high-pressure line failures in consideration of the effects of both pressure and low temperature.

18.4.4 Fuel Consumer Isolation

1 Supply piping for fuel consumers is to be provided with automatic double block and bleed valves so that fuel can be isolated during both normal and emergency operations. In addition, such valves are to be vented using the vent systems described in **18.3.4**., under both normal and emergency operation. In addition, such valves are to be arranged to fail to the closed position upon the loss of actuating power, and. In spaces containing multiple fuel consumers, the shutdown of the supply to one fuel consumer is to not affect the supply to other fuel consumers located in the same space.

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

3 Arrangements to prevent back-flow of fuel vapour into inert gas systems are to be provided as specified below. Inert gas supply lines are to be fitted with two shutoff valves in series with venting valves (double block and bleed valves) in between and closable non-return valves installed between double block and bleed valve arrangements and fuel systems. In addition, such valves are to not be installed in non-hazardous areas.

Note
・Materials used for piping downstream of pressure relief valves and downstream of bleed valves are to be selected in consideration of the effects of temperature reductions caused by changes in state during fuel release. ・Piping design pressures for piping downstream of pressure relief valves and downstream of bleed valves are to be determined in consideration of the effects of temperature reductions caused by changes in state during fuel release.

18.4.5 Spaces Containing Fuel Consumers

1 It is to be possible to isolate the gas fuel supplies to individual spaces containing fuel consumers or through which fuel supply piping is run with individual master valves that are located within cargo areas. The isolation of the gas fuel supply to a space is to not affect the gas supplies to other spaces containing fuel consumers if they are located in two or more spaces, and it is to not cause a loss of propulsion or electrical power.

2 If the double barrier around the fuel supply system is not continuous due to air inlets or other openings, the individual master valve for the space is to operate under the following circumstances.

(1) The valve closes automatically in the following cases:

(a) gas detection within the space; and

(b) fuel detection in the annular space of a double-walled pipe.

(2) The valve can be manually closed from within the space, and at least from one other remote location.

3 If the double barrier around the fuel supply system is continuous, an individual master valve located in the cargo area may be provided for each fuel consumer inside the space. The individual master valve is to operate under the following circumstances.

(1) The valve closes automatically in the following cases:

(a) leak detection in the annular space of a double-walled pipe served by that individual master valve; and

(b) leak detection in other compartments containing single-walled gas piping that is part of the supply system served by the individual master valve.

(2) The valve can be manually closed from within the space, and from at least one other remote location.

18.4.6 Piping and Ducting Construction

1 Gas fuel piping in machinery spaces is to comply with **Chapter 5, Part N of the Rules**, as applicable. The piping is, as far as practicable, to have welded joints. Those parts of the fuel piping that are on weather decks outside of cargo areas are to have full penetration butt-welded joints and are to be subject to the non-destructive tests described in **16.6.3**.

2 Connections of fuel piping and ducting to fuel injection valves are to be completely covered by ducting. Such arrangements are to facilitate the replacement and overhaul of injection valves and cylinder covers. In addition, double ducting is also required for all gas pipes installed on the engine itself up to the fuel valves in chambers.

3 Secondary enclosures are to be gastight towards adjacent spaces.

4 Leaked fuel into secondary enclosures is to be properly treated.

5 Expansion joints for fuel pipes are to be of an approved type.

18.4.7 Ventilation of Secondary Enclosures

1 For ventilation of secondary enclosures to protect fuel pipes, FVU rooms and similar spaces, **12.1.7, 12.1.9 and 12.1.10, Part N of the Rules** as well as the following **-2** to **-7** apply.

2 Exhaust ventilation systems are to be installed in secondary enclosures that protect the fuel pipes, FVU chambers and similar spaces. Such ventilation systems are to be capable of ventilating at least 30 *times* per hour based on the total capacity of the space and are to operate under all temperature and environmental conditions that may occur on the ship.

3 The spaces specified in **-1** above that are required to be entered during normal operations are to always be ventilated.

4 In addition to **-1** above, increased ventilation systems are to have a minimum capacity of at least 45 *air changes* *per hour* based upon the total volume of space due to remove leaked ammonia from the space. The ventilation capacity described above may include the ventilation capacity of mechanical ventilation in the enclosed or semi-enclosed spaces described in **-2** above. When the gas concentration in the space exceeds 300 *ppm*, the mechanical ventilation is to automatically activate.

5 Mechanical ventilation in spaces not normally entered is to automatically activate after the detection of gas. The mechanical ventilation in the space is to be manually started for maintenance, etc.

6 Mechanical ventilation and its associated ducts are to be as follows.

(1) Independence from ducts used for ventilation in non-hazardous areas.

(2) Prohibition of passage through accommodation spaces, service spaces and control stations.

(3) Prevent of accumulation of leaked fuel in ventilation systems at any position.

(4) Arrangement of ventilation outlets in safe places in the atmosphere, taking into account ammonia leakage.

(5) Air outlets for hazardous enclosed spaces are to be located in open areas that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

7 The number and power of ventilation fans are to not be such that the capacity is reduced by more than 50% of total ventilation capacity even if the following fans cannot be used.

(1) Fans with separate circuits from main switchboards or emergency switchboards.

(2) Groups of fans with common circuits from main switchboards or emergency switchboards.

Note: When power is not supplied to ventilation fans due to failures of distribution boards or wiring equipment downstream of main switchboards and emergency switchboards, total ventilation capacity is to not be less than 50%.

18.4.8 Gas Detection

1 Gas detectors are to be arranged for detecting fuel leakage. For gas detectors, **Chapter 13, Part N of the Rules** and the following of **-2** to **-4** apply.

2 Gas detection systems provided in accordance with the requirements of this chapter are to activate alarms at 25 *ppm* and shut down the master fuel valve required by **18.4.6** before reaching 300 *ppm*.

3 In addition to **-1** above, the following **(1)** and **(2)** are to be satisfied.

(1) Audible and visual alarms for permanent gas detectors are to give warnings as specified in **-4** below.

(2) Gas detection is to be continuous without delay.

4 Permanently installed gas detectors are to be fitted in the following:

(1) spaces containing fuel consumers,

(2) FVU rooms,

(3) the secondary enclosures described in this chapter, and

(4) expansion tanks of systems that exchange heat with fuel.

18.5 Fuel Conditioning Systems and Associated Storage Tanks

18.5.1 Requirements for Fuel

Fuel conditioning equipment is, in principle, to be located in cargo areas. If such equipment is located in enclosed spaces on weather decks, such spaces are considered to be cargo machinery rooms and are to be ventilated according to **12.1, Part N of the Rules**; moreover, such spaces are to be provided with fixed fire extinguishing systems in accordance with **11.5, Part N of the Rules** and gas detection equipment in accordance with **13.6, Part N of the Rules**. However, spaces where only pipes and valves used for fuel supply are arranged may be considered FVU rooms.

18.5.2 Remote Stops

1 Rotating equipment utilised for fuel conditioning is to be arranged for manual remote stop from engine rooms. Additional remote stops are to be located in areas that are always easily accessible, typically near the exits of cargo machinery rooms, cargo control rooms, navigation bridges and fire control stations.

2 Fuel supply equipment is to be automatically stopped in the case of low suction pressure or fire detection. Unless expressly provided otherwise, the requirements of **18.3, Part N of the Rules** need not apply to fuel compressors or pumps when used to supply fuel consumers.

18.5.3 Heating and Cooling Media

1 If heating or cooling media for gas fuel conditioning systems are returned to spaces outside of cargo areas, arrangements are to be made to detect and warn of the presence of ammonia in the medium. Vent outlets are vent into the atmosphere from safe locations.

2 Where gas can leak directly into auxiliary system media (lubricating oil, cooling water), an appropriate means is to be provided to extract gas in order to prevent gas dispersion. Gas extracted from auxiliary system media is to be vented into the atmosphere from safe locations.

18.5.4 Piping and Pressure Vessels

Piping or pressure vessels fitted in gas fuel supply systems are to comply with **Chapter 5, Part N of the Rules**.

18.6 Special Requirements for Main Boilers and Auxiliary Boilers

18.6.1 Arrangements

1 Boilers are to have separate exhaust uptakes.

2 Boilers are to have dedicated forced draught systems. In addition, crossovers between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

3 Boiler combustion chambers and uptakes are to be so designed to prevent any accumulation of gaseous fuel.

18.6.2 Combustion Equipment

1 Burner systems are to be of a dual type, suitable to burn either oil fuel or fuel alone, or oil and fuel simultaneously.

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

3 Automatic systems are to be fitted to change over from gas fuel operations to oil fuel operations without the interruption of the boiler firing in the event of a loss of fuel supply.

4 Gas nozzles and burner control systems are to be configured so that fuel can only be ignited by an established oil fuel flame except in those cases approved by the Society in which the combustion equipment is designed to ignite on gas-fuel.

18.6.3 Safety

1 Arrangements are to be provided to ensure that fuel flow to burners is automatically cut-off unless satisfactory ignition has been established and maintained.

2 Manually operated shut-off valves are to be fitted to gas burner fuel pipes.

3 Arrangements are to be made for automatically purging fuel supply piping to burners by inert gas after extinguishing burners.

4 The automatic fuel changeover systems required by **18.6.2-3** are to be monitored with alarms to ensure continuous availability.

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

6 Arrangements are to be made to enable boilers to be manually purged.

18.7 Special Requirements for Gas-fired Internal Combustion Engines

Dual fuel engines are those that use ammonia fuel (with pilot oil) and oil fuel. Oil fuels may include distillate and residual fuels. Fuel only engines are those that use ammonia fuel only.

18.7.1 Arrangements

1 Engines are to have their own separate exhaust piping.

2 Exhaust piping is to be configured to prevent any accumulation of unburnt gaseous fuel.

3 Air inlet manifolds, scavenge spaces, exhaust system and crankcases are to be fitted with suitable pressure relief systems except in cases where designed with sufficient strength to withstand the worst case of overpressure due to ignited fuel leaks. Such pressure relief systems are to vent into the atmosphere from safe locations (i.e. away from ship personnel). Pressure relief systems that do not discharge gas, however, need not vent into the atmosphere from safe locations.

4 Engines other than two-stroke crosshead diesel engines are to be fitted with vent systems for crankcases and sumps that are independent of the vent systems for other engine crankcases and sumps. Gas extracted from such vent systems is to be vented to into the atmosphere from safe locations.

5 For trunk type engines (i.e. engines without diaphragms between their crankcases and cylinder spaces) below pistons, 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.

6 Scavenge spaces and air inlet manifolds are to be configured to prevent any accumulation of unburnt fuel.

18.7.2 Combustion Equipment

1 Prior to the admission of fuel, the correct operation of the pilot oil injection system on each unit is to be verified.

2 If ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, the valve is to be automatically shut off and the starting sequence terminated. It is to be ensured that any unburnt gas mixture is purged from the exhaust system.

3 Automatic systems are to be provided to change over from gas fuel operations to oil fuel operations with minimum fluctuations of engine power.

4 In the case of unstable operation on engines with the arrangements specified in **-3** above when gas firing, the engine is to automatically change over to oil fuel mode.

5 Ammonia fuel injection valves are to consider the following.

(1) Ammonia fuel injection valves are to possess satisfactory operating characteristics and durability for the assumed service period

(2) Ammonia fuel valves are to be provided with sealing systems to effectively prevent fuel from leaking through gaps around valve spindles

(3) Appropriate means are to be provided in cases where fuel injection valve actuating oil is required to be kept clean.

18.7.3 Safety

1 During the stopping of engines, fuel is to be automatically shut off before ignition sources.

2 Arrangements are to be provided to ensure that there is no unburnt gas fuel in exhaust gas systems prior to ignition.

3 Crankcases, sumps, scavenge spaces and cooling system vents are to be provided with gas detection. This, however, does not apply to vents for the crankcases and sump tanks of crosshead-type engines.

4 Engines are to be so design to permit continuous monitoring of possible crankcase ignition sources. Instrumentation fitted inside crankcases is to be in accordance with the requirements of **Chapter 10, Part N of the Rules**.

5 A means is to be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply is to be shut down. Instrumentation fitted inside the exhaust system is to be in accordance with the requirements of **Chapter 10, Part N of the Rules**.

18.8 Flammable Hazardous Areas Other Than Cargo Areas

18.8.1 Classification

1 Zone 0 hazardous areas include but are not limited to the following:

(1) Pipework for fuel pipes, venting pipes and equipment containing fuel.

2 Zone 1 hazardous areas include but are not limited to the following:

(1) Enclosed or semi-enclosed spaces in which pipes containing fuel are located. (e.g. secondary enclosures, FVU rooms)

Note:
・The condition "except those where pipes containing cargo products for boil-off gas fuel burning systems are located" in **1.1.4(23)(k), Part N of the Rules** does not apply in the Guidelines.
・Spaces around air intakes on open decks in front of **(1)** are not included in flammable hazardous areas.

3 Zone 2 hazardous areas include but are not limited to the following:

(1) Airlocks

18.9 Toxic Hazardous Areas Other Than Cargo Areas

18.9.1 Definition

1 Toxic hazardous area refers to the following areas:

(1) Toxic hazardous area

Zone 0: Areas or spaces in which an ammonia is either continuously present or is present for long periods of time.

Zone 1: Areas or spaces in which ammonia gas that is hazardous to human health regularly generated or rarely generated under normal conditions.

Zone 2: Areas or spaces in which ammonia gas that is hazardous to human health is to not likely to be generated under normal conditions, but the areas around Zone 1 areas in which such gas can only exist for a short time if generated.

(2) Non-toxic hazardous areas

Areas other than the above in which there is no ammonia gas generated that is hazardous to human health.

(3) Classification methods for toxic hazardous areas are to be in accordance with **H4.2.3**, **Part H of the Guidance**.

18.9.2 Classification

In addition to **1.1.4(23), Part N of the Rules**, toxic hazardous areas are classified as follows.

1 Zone 0 hazardous areas include but are not limited to the following:

(1) areas or spaces containing fuel pipes, venting pipes and equipment containing fuel.

2 Zone 1 hazardous areas include but are not limited to the following:

(1) Enclosed or semi-enclosed spaces in which pipes containing fuel are located. (e.g. secondary enclosures, FVU rooms);

Note
・The condition "except those where pipes containing cargo products for boil-off gas fuel burning systems are located" referred to in **1.1.4(23)(k), Part N of the Rules**) does not apply to the requirements in the Guidelines.
・Spaces around air intakes on open decks in front of **(1)** are not included in flammable hazardous areas.

(2) Areas on open deck or semi-enclosed spaces on deck, within [1.5 m] of openings into Zone 1 spaces;

(3) Airlocks.

3 Zone 2 hazardous areas include but are not limited to the following:

(1) Areas within [1.5 *m*] surrounding open or semi-enclosed spaces of Zone 1;

(2) Airlocks.

Note: Items in Square brackets ([ ]) have yet to finalized, and thus may be modified or deleted as deemed necessary based on future discussions.

18.9.3 Safety Requirements for Toxic Ammonia

In order to minimize the effects of ammonia on ships and humans due to toxic ammonia, the safety requirements specified in **Chapter 14B** apply to the toxic hazardous areas and other relevant locations specified in **9.2.**

18.10 Operating Requirements

18.10.1 Application

The requirements of this **18.10** 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 ship master as well as all other ship personnel responsible for ship operation.

18.10.2 Manual Purging of Boilers

Combustion chambers of boilers are to be manually purged as needed in consideration of **18.6.3**.

18.10.3 Personal Protective Equipment

Proper personal protective equipment is to be worn according to the type of work with consideration being given to ammonia toxicity. Risk assessments of types of work are to be carried out to determine whether personal protective equipment is necessary.

18.10.4 Accessing Hazardous Areas

When entering areas or spaces where there is a possibility of gas leakage, verify the following.

(1) Sufficient ventilation is provided.

(2) Gas detectors and oxygen analysers are operating normally.

(3) Concentrations of gas and oxygen are appropriately checked and recorded.

(4) Ammonia gas is to be confirmed to not be present.

(5) Whether personal protective equipment is required to be used when fuel is present.

18.11 Operation Manuals

18.11.1 Operation Manuals

Operation manuals are to include information related to the following **(1)** and **(2)** in addition to the information required by **Chapter 18, Part N of the Rules**.

(1) Operation of ventilation systems, dampers, etc. in hazardous areas.

(2) Temperature, pressure control, alarms, and safety devices for fuel supply systems.

Annex 1

Alternative Fuel Ready

Annex 1 Alternative Fuel Ready **1**
Chapter 1 General **1**
1.1 General 1
1.2 Class Notation 3
Chapter 2 Design Approval **4**
2.1 General 4
2.2 Documentation 4
Chapter 3 Surveys **9**
3.1 General 9

Annex 1 Alternative Fuel Ready

Chapter 1 General

1.1 General

1.1.1 Application

1 This annex applies to ships classed with the Nippon Kaiji Kyokai (hereinafter referred to as "the Society"), that take measures beforehand in preparation for possible future conversion to the becoming a ship using alternative fuel for which an application to affix relevant notation to the ship's classification characters is made. The term "measures" in this context means that the ship has either a concept design for future conversion, or both a concept design and detailed design for partial facilities related to alternative fuel use and associated installations. Hereinafter, such measures are referred to as "Alternative Fuel Ready", and this also applies to ships using alternative fuels that are designed for the use of other alternative fuels in the future.

2 The scope of Alternative Fuel Ready is to be determined through an agreement between shipyards and shipowners on a per ship basis .

3 Ships to which this annex may be applied are to be as follows.

(1) In consideration of the type of alternative fuel to be used, concept designs (see **1.1.3(1)**) are to be conducted based on **Part GF of the Rules for the Survey and Construction of Steel Ships**, the **Guidelines for Ships Using Alternative Fuels**, and other related requirements (hereinafter referred to as "related requirements"). In addition, the plans and documents listed in **2.2.1** are to be submitted to the Society for review.

(2) For ships categorised as Alternative Fuel Ready to which the items listed in **1.1.3(2)** to **(7)** apply, the plans and documents listed in **2.2.2** are to be submitted and approved by the Society, in addition to those required by **(1)** above. Such facilities are to be installed on the ship and confirmed by the related survey. Facilities listed in **1.1.3(1)** to **(7)** that are marked by ※**1** are to be designed in accordance with the requirements of this annex, but their actual installation may be decided based on agreements between shipyards and shipowners.

In addition a list of items to be implemented at the stage of Alternative Fuel Ready and the items that require detailed design and modification in the future (see **2.2.1 (1) (a)**) is to be submitted to the Society.

1.1.2 Premise

1 The Alternative Fuel Ready requirements specified in this annex provide an excerpt of some concept designs for using alternative fuels and some ways of classifying the main associated equipment into categories, but they do not cover all the designs and equipment needed to use alternative fuels. Therefore, additional designs and equipment may be required in some cases when a ship is modified to use alternative fuels.

2 When applying this annex, it is not necessary to submit a report of risk assessments identifying hazards required by the related requirements, such as HAZID (Hazard Identification) meetings, which are required by the relevant requirements. Such reports, however, are to be submitted to the Society when a ship to which this annex is applied is modified to use alternative fuels.

3 When ships to which this annex is applied are modified to use alternative fuels, the plans and documents required by **2.1, Part B of Rules for the Survey and Construction of Steel Ships** and the related requirements are to be submitted to the Society. In some cases, though, part of these plans and documents may be omitted provided that the plans and documents described in **2.2.2**, which are submitted at the stage of Alternative Fuel Ready, include all necessary information.

4 When applying this annex, the latest related requirements at the time of application are to apply to the ship as the safety requirements for structures and equipment. When the ship is actually modified to use alternative fuels, it is necessary to comply with the related requirements applicable at that time. With respect to **-3** above, it might be necessary to revise plans that have already been approved at the Alternative Fuel Ready stage.

1.1.3 Alternative Fuel Ready Categories

Alternative Fuel Ready is categorized into the following seven categories.

(1) Concept Design

Concept Design means that a concept design for the use of alternative fuels has been done and it has been confirmed according to requirements of the related requirements. This category is mandatory when applying this annex.

(2) Hull Structure

Hull Structure means that the ship has been designed and equipped with an actual hull structure intended to satisfy the requirement for arrangements of alternative fuel tanks and hold spaces in consideration of tank type, local strength of surrounding hull structures, and steel grade.

(3) Fuel Containment System

Fuel Containment System means that the ship has been designed and equipped with actual equipment for fuel containment, such as alternative fuel tanks, tank valves, related pipes in tanks, pressure relief systems, measurement or monitoring systems, secondary barriers, and supporting structures. Its scope also includes pressure relief systems[*1], bilge systems[*1], fire protection means[*1], ventilation systems[*1], and gas detection systems[*1] for hold spaces and tank connection spaces.

(4) Bunker Station

Bunker Station means that the ship has been designed and equipped with actual equipment for bunkering, such as bunkering stations for alternative fuel, bunkering lines from manifolds to tanks as well as associated inerting lines and pressure relief systems, valves and pipe fittings, and measurement systems. Its scope also includes the fire protection means[*1], ventilation systems[*1], gas detection systems[*1], and monitoring systems[*1] related to bunkering stations for alternative fuel.

(5) Fuel Supply System

Fuel Supply System means that the ship has been designed and equipped with actual equipment for fuel supply, such as fuel supply lines outside of engine rooms as well as associated inerting lines and pressure relief systems, valves and pipe fittings, alternative fuel processing equipment, and measurement systems. Its scope also includes fire protection means[*1], ventilation systems[*1], gas detection systems[*1], and monitoring systems[*1] related to the areas where equipment for fuel supply is installed.

(6) Pressure and Temperature Management System

Pressure and Temperature Management System means that the ship has been designed and equipped with actual equipment for pressure and temperature control, such as gas secondary treatment systems to manage the pressure and temperature control in alternative fuel tanks (hereinafter referred to as “secondary systems”), associated pipes from tanks to secondary systems, valves, and pipe fittings. Its scope also includes fire protection means[*1], ventilation systems[*1], gas detection systems[*1], and monitoring systems[*1] related to the areas where secondary systems are installed.

(7) Alternative Fuel Consumer

Alternative Fuel Consumer means that the ship has been designed and equipped with actual equipment which consumes alternative fuel, such as main or generator engines powered by alternative fuels, associated pipes in engine rooms, valves, and pipe fittings. Its scope also includes fire protection means[*1], ventilation systems[*1], gas detection systems[*1], and monitoring systems[*1] installed engine rooms.

[*1] The design of this equipment or system is, in principle, to comply with the requirements of this annex and the related requirements; actual installation, however, may be decided based on agreements between shipyards and shipowners in

accordance with **1.1.1-3. (2)**. Such equipment or systems are to be actually installed at the Alternative Fuel Ready stage described in **2.2.1 (1) (a)**.

1.2 Class Notation

1.2.1 General

Ships that have been confirmed as complying with the additional requirements described in this annex may have the following "(fuel type) Fuel Ready" notation affixed to their classification characters in accordance with the type of fuel .

(1) LNG Fuel Ready (Abbreviation: LNG FR)
(2) Methanol Fuel Ready (Abbreviation: MA FR)
(3) Ethanol Fuel Ready (Abbreviation: EA FR)
(4) LPG Fuel Ready (Abbreviation: LPG FR)
(5) Ammonia Fuel Ready (Abbriviation: AM FR)

1.2.2 Additional Characters

Additional characters may be affixed with the "Alternative Fuel Ready" speficied in 1.2.1 corresponding notation corresponding to the implementation status of each category in **1.1.3**. These additional characters are specified as follows.

(1) C: Ships that have implemented measures for *Concept Design*
(2) S: Ships that have implemented measures for *Hull Structure*
(3) T: Ships that have implemented measures for *Fuel Containment System*
(4) B: Ships that have implemented measures for *Bunker Station*
(5) F: Ships that have implemented measures for *Fuel Supply System*
(6) P: Ships that have implemented measures for *Pressure and Temperature Management System*
(7) A: Ships that have implemented measures for *Alternative Fuel Consumer*

In the case of *Alternative Fuel Consumer*, the additional characters are further categorized as follows based on the status of the consumer installation.

Alternative Fuel Facility	Additional Character
Main engines	AM
Auxiliary engines	AG
Other	AO

＜Example of notation with additional characters＞

In cases where a ship plans to use LNG as fuel and also has the hull structure needed to install the fuel tanks, main engines and associated pipes for LNG fuel upon completion of ship construction, provided that these comply with the requirements for *Concept Design*, *Hull Structure*, and *Alternative Fuel Consumer*, the ship's notation may be given as follows.

Notation for Alternative Fuel Ready: LNG Fuel Ready (Concept Design, Hull Structure, Alternative Fuel Consumer: Main Engine)

Abbreviation: LNG FR(C, S, AM)

Chapter 2 Design Approval

2.1 General

1 Ships to which this annex is applied are to be designed based on the related requirements in accordance with the type of fuel to be used. In addition, the plans and documents listed in **2.2.1** and **2.2.2** are to be submitted to the Society for review.

2 Plans and documents may be omitted provided that these are not needed considering the characteristics of alternative fuels. As an example, when implementing *Hull Structure* assuming the fuel containment system stores methanol at room temperature, it is not necessary to submit temperature distribution calculation sheets for hull structures around the fuel containment system and material selection sheets.

3 According to **1.1.1-3(2)**, the plans specified in **2.2.2** are to clearly indicate the items to be implemented at the Alternative Fuel Ready stage and the items that will require detailed design and future modification. In addition, a list showing each item (see **2.2.1(1)(a)**) is to be prepared and submitted to the Society.

2.2 Documentation

2.2.1 Plans and Documents for Concept Design

For ships to which this annex is applied, the following plans and documents listed in the following **(1)(a)** and **(1)(b)** are to be submitted to the Society for review. The "specifications of concept design" is a document that shows the concept design when the ship uses alternative fuels in the future. Even if the contents of the specifications of concept design overlap with information contained in the plans and documents submitted in accordance **2.1** of **Part B of Rules for the Survey and Construction of Steel Ships**, such specifications are to be submitted separately to show the plans after conversion.

(1) Plans and documents for the additional character "C" / *Concept Design*

(a) A list showing the items to be implemented at the Alternative Fuel Ready stage and the items that will require detailed design and future modification

It is not necessary to submit this list in cases where the ship only complies with the requirements for *Concept Design*.

(b) Specifications of concept design

A specifications of concept design is to include the following information.

i) General arrangement

ii) Longitudinal strength calculation sheets

iii) Navigation bridge visibility (only in cases where alternative fuel tanks installed on open decks affect visibility)

iv) Trim and intact stability calculations

v) Damage stability calculations

vi) Fire protection structural plans (including arrangements of cofferdams)

vii) Fire extinguishing arrangement plans

viii) Arrangements for access to hazardous areas, fuel preparation rooms, tank connection spaces, ESD-protected machinery spaces, and inerted spaces as well as guides for said access thereto (including airlocks)

ix) Piping diagrams for fuel supply, fuel gauging, and fuel venting (including major fuel supply facilities, piping systems, and pipe fittings)

x) Drawings showing distances between fuel tanks and shell plates at each section (including probability calculation sheets in cases where a probabilistic approach is used to decide fuel tank arrangements)

xi) Plans showing hazardous areas

xii) Fuel containment system specifications (including methods for pressure and temperature control, design pressure and temperature, and dimensions of alternative fuel storage tanks)

xiii) Alternative fuel consumer specifications (including particulars of alternative fuel engines and concepts of ESD systems)

xiv) Other plans and documents specially requested by the Society

2.2.2 Plans and Documents for Other Categories

For ships to which **1.1.3(2)** to **(7)** of this annex are applied, the following plans and documents are to be submitted to the Society for approval in addition to those required by **2.2.1**. For ships applying for Classification Surveys during Construction by the Society, it is not necessary to separately submit plans and documents that overlap with those required by **2.1.2** and **2.1.3** of **Part B of Rules for the Survey and Construction of Steel Ships**. However, such plans and documents are to include the equipment and facilities based on each implemented category.

(1) Plans and documents for the additional character "S" / *Hull Structure*

Plans and documents for approval

(a) Construction plans for hull structures around fuel containment systems

(b) Other plans and documents specially requested by the Society

Other plans and documents

(c) Local strength calculation sheets for hull structures around fuel containment systems (including supporting structures)

(d) Temperature distribution calculation sheets for hull structures around fuel containment systems and material selection sheets

(e) Other plans and documents specially requested by the Society

(2) Plans and documents for the additional character "T" / *Fuel Containment System*

Plans and documents for approval

(a) Construction plans for alternative fuel tanks

(b) Manufacturing specifications for alternative fuel tanks (including welding procedures, inspection and testing procedures for welds and tanks, and working standards)

(c) Accessory system drawings and arrangements for alternative fuel tanks (including details of internal fittings)

(d) Supporting strcuture arrangements and construction plans for alternative fuel tanks (including rolling chocks and anti-floatation arrangements)

(e) Construction plans for alternative fuel tank deck portions through which alternative fuel tanks penetrate, and their sealing arrangements

(f) Secondary barrier arrangements and construction plans

(g) Thermal insulation arrangements and detailed installation plans for alternative fuel tanks

(h) Thermal insulation procedures for alternative fuel tanks

(i) Arrangements of equipment installed in tank connection spaces

(j) Piping diagrams for the fuel supply, fuel gauging and fuel venting of alternative fuel tanks (including the materials used, dimensions, kinds, design pressures, design temperatures, etc. of pipes and valves, etc.)

(k) Bilge systems in spaces surrounding alternative fuel tanks

(l) Pressure relief system details for spaces surrounding alternative fuel tanks (including details of drainage systems for liquid fuels in cases where type *A* independent tanks are installed)

(m) Ventilation system arrangments and construction plans for spaces surrounding alternative fuel tanks (including materials, ventilation capacity, etc.)

(n) Fire protection construction plans for spaces surrounding alternative fuel tanks (including cofferdam arrangements)

(o) Electrical equipment tables for spaces surrounding alternative fuel tanks (including gas detectors and lights)

(p) Fixed gas detector arrangments for spaces surrounding alternative fuel tanks

(q) Control system diagrams for alternative fuel tanks (including monitoring, safety, and alarm systems) and lists of associated settings

(r) Electrical bonding arrangements for alternative fuel tanks and associated piping systems, etc.

(s) Inspection orsurvey plans for alternative fuel tanks and surrounding spaces

(t) Other plans and documents specially requested by the Society

Other plans and documents

(u) Strength calculation sheets for alternative fuel tanks

(v) Strength calculation sheets for associated supporting structures

(w) Other plans and documents specially requested by the Society

(3) Plans and documents for the additional character "B" / *Bunker Station*

Plans and documents for approval

(a) Arrangements of equipment installed in alternative fuel bunkering stations

(b) Piping diagrams for the fuel supply, fuel gauging, and fuel venting of bunkering lines (including the materials used, dimensions, kinds, design pressures, design temperatures, etc. of pipes and valves, etc.)

(c) Ventillation system arrangments and construction plans for alternative fuel bunkering stations as well as for associated double-wall pipes and ducts (including the materials used, ventilation capacity, etc.)

(d) Details and specifications for alternative fuel bunkering manifolds, valves, couplings, and other fittings (including the materials used and dimensions)

(e) Fire protection construction plans for alternative fuel bunkering stations

(f) Electrical equipment tables for alternative fuel bunkering stations (including gas detectors and lights)

(g) Manufacturing specifications for bunkering lines (including welding procedures, inspection and testing procedures for welds and tanks, and working standards)

(h) Fixed gas detector arrangments for alternative fuel bunkering stations, as well as for associated double-wall pipes and ducts

(i) Control system diagrams for bunkering lines (including monitoring, safety, and alarm systems) and lists of associated settings

(j) Electrical bonding arrangements for bunkering lines, etc.

(k) Other plans and documents specially requested by the Society

(4) Plans and documents for the additional character "F" / *Fuel Supply System*

Plans and documents for approval

(a) Arrangements of equipment installed in fuel preparation rooms

(b) Piping diagrams for the fuel supply, fuel gauging, and fuel venting of fuel supply systems (including the materials used, dimensions, kinds, design pressures, design temperatures, etc. of pipes and valves, etc.)

(c) Ventilation system arrangments and construction plans for fuel preparation rooms as well as for associated double-wall pipes and ducts (including the materials used, ventilation capacity, etc.)

(d) Details and specifications for compressors and pumps

(e) Details and specifications for vapourisers, heaters, and pressure vessels
(f) Details and specifications for the valves and other fittings of fuel supply system piping
(g) Fire protection construction plans for fuel preparation rooms
(h) Electrical equipment tables for fuel preparation rooms (including gas detectors and lights)
(i) Manufacturing specifications for fuel supply system piping (including welding procedures, inspection and testing procedures for welds and tanks, and working standards)
(j) Fixed gas detector arrangments for fuel preparation rooms as well as for associated double-wall pipes and ducts
(k) Control system diagrams for fuel supply systems (including monitoring, safety, and alarm systems) and lists of associated settings
(l) Electrrical bonding arrangements for fuel supply systems, etc.
(m) Other plans and documents specially requested by the Society

(5) Plans and documents for the additional character “P” / *Pressure and Temperature Management System*

Plans and documents for approval

(a) Arrangements of equipment installed in spaces where secondary systems are installed
(b) Piping diagrams for the fuel supply, fuel gauging, and fuel venting of secondary systems (including the materials used, dimensions, kinds, design pressures, design temperatures, etc. of pipes and valves, etc.)
(c) Ventilation system arrangments and construction plans for spaces where secondary system are installed as well as for associated double-wall pipes and ducts (including the materials used, ventilation capacity, etc.)
(d) Details and specifications of secondary systems (including treatment capacity)
(e) Fire protection construction plans for spaces where secondary systems are installed
(f) Electrical equipment tables for spaces where secondary systems are installed (including gas detectors and lights)
(g) Manufacturing specifications for secondary system piping (including welding procedures, inspection and testing procedures for welds and tanks, and working standards)
(h) Fixed gas detector arrangments for spaces where secondary systems are installed as well as for associated double-wall pipes and ducts
(i) Control system diagrams for spaces where secondary systems are installed (including monitoring, safety, and alarm systems) and lists of associated settings
(j) Electrical bonding arrangements for secondary systems, etc.
(k) Other plans and documents specially requested by the Society

(6) Plans and documents for the additional character “A” / *Alternative Fuel Consumer*

Plans and documents for approval

(a) Arrangements of machinery in machinery spaces (including arrangements for alternative fuel engines, gas turbines, boilers, gas combustion units, and fuel supply lines)
(b) Piping diagrams for the fuel supply, fuel gauging, and fuel venting of machinery spaces (including the materials used, dimensions, kinds, design pressures, design temperatures, etc. of pipes and valves, etc.)
(c) Ventilation system arrangments and construction plans for machinery spaces as well as for associated double-wall pipes and ducts (including the materials used, ventilation capacity, etc.)
(d) Details and specifications of alternative fuel consumers, such as alternative fuel engines, gas turbines, boilers, and gas combustion units
(e) Fire protection construction plans for machinery spaces
(f) Electrical equipment tables for machinery spaces (including gas detectors and lights)

(g) Manufacturing specifications for alternative fuel consumer piping (including welding procedures, inspection and testing procedures for welds and tanks, and working standards)
(h) Fixed gas detector arrangments for machinery spaces as well as for associated double wall pipes and ducts
(i) Control system diagrams for machinery spaces (including monitoring, safety, and alarm systems) and lists of associated settings
(j) Electrical bonding arrangements for secondary systems, etc.
(k) Other plans and documents specially requested by the Society

Chapter 3 Surveys

3.1 General

3.1.1 Initial Surveys

Where parts of alternativ fuel facilities are installed based on the ranges agreed to by shipbuilers and shipowners (see **2.2.1(1)(a)**), such parts are to be surveyed as requested in accordance with applicable requirements of **2.1.4.1** and **2.1.4.2** of **Part B of Rules for the Survey and Construction of Steel Ships**.

3.1.2 Maintenance Surveys

Maintenance surveys are to be carried out of hull constructions and alternative fuel facilities registered as being Alternative Fuel Ready in accordance with **3.2** and **3.3** of **Part B of Rules for the Survey and Construction of Steel Ship** before alternative fuel use begins. Furthermore, when ships are modified for alternative fuel use, general inspections and performance tests are to be conducted in accordance with **Chapter 5** of **Part B of Rules for the Survey and Construction of Steel Ships**.

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[English]

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