

**RUSSIAN MARITIME REGISTER OF SHIPPING**

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**RULES**  
**FOR THE CLASSIFICATION**  
**AND CONSTRUCTION**  
**OF SHIPS CARRYING LIQUEFIED**  
**GASES IN BULK**

ND No. 2-020101-140-E



Saint-Petersburg  
2021

The Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk have been approved in accordance with the established approval procedure and come into force on 1 January 2021.

The present edition is based on the latest version of the Rules, 2020.

The Rules set the requirements, which are specific for the ships carrying liquefied gases in bulk, and supplement the Rules for the Classification and Construction of Sea-Going Ships and the Rules for the Equipment of Sea-Going Ships of Russian Maritime Register of Shipping.

## REVISION HISTORY

(purely editorial amendments are not included in the Revision History)

Amended paras/chapters/sections	Information on amendments	Number and date of the Circular Letter	Entry-into-force date
Part V, para 3.2.2	A new para with requirements for emergency fire pump capacity when total flooding high expansion foam system is fitted protecting the engine-room has been introduced considering IACS UI GC30 (Apr 2020)	313-14-1468c of 24.11.2020	01.01.2021
Part V, para 3.2.3	A new para with requirements for emergency fire pump capacity for supplying fire-extinguishing system with maximum water coverage has been introduced considering IACS UI GC30 (Apr 2020)	313-14-1468c of 24.11.2020	01.01.2021
Para V, para 3.3.6	Requirements for operation of water-spray system from emergency fire pump have been specified considering IACS UI GC22 (Rev.1 Apr 2020)	313-14-1468c of 24.11.2020	01.01.2021
Part V, para 3.4.11	Requirements for operation of dry chemical powder fire-extinguishing system have been specified considering IACS UI GC31 (June 2020)	313-14-1468c of 24.11.2020	01.01.2021
Part VI, para 2.1.1	A reference to another Part of the Rules has been specified	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 2.1.5	A new para with the requirements for selection of material for outer pipes and ducts of gas fuel system has been introduced considering IACS UR G3 (Rev.7 Dec 2019)	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 2.2.1.1	Requirements for design pressure of outer pipes and ducts of gas fuel system have been specified considering IACS UR G3 (Rev.7 Dec 2019)	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 2.2.2	Requirements for minimum pipe wall thickness system have been specified considering IACS UR G3 (Rev.7 Dec 2019)	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 2.3.6	Requirements for bellows have been specified considering IACS UR G3 (Rev.7 Dec 2019)	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 8.1.6	Requirements for ventilation exhaust ducts have been specified	313-79-1477c of 02.12.2020	01.01.2021
Part VI, para 12.1.1.1.1.1	Requirements for type tests of valves used at a working temperature above –55 °C have been specified	313-79-1477c of 02.12.2020	01.01.2021
Part VII, para 1.2.1	Additional explanation to the definition "hazardous zone" regarding the categories of hazardous zones has been introduced considering IGC Code.	315-06-1490c of 28.12.2020	01.02.2021
Part VII, paras 2.2.1, 2.2.1.1 and 2.2.1.1.1	The structure of the paras has been amended regarding specific requirements for gas carriers in terms of division into hazardous zones considering IEC 60092-502	315-06-1490c of 28.12.2020	01.02.2021

## **PART I. CLASSIFICATION**

### **1 GENERAL**

#### **1.1 Application.**

**1.1.1** Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk<sup>1</sup> apply to specially built or converted ships, regardless of their gross tonnage and power plant output, intended for the carriage of liquefied gases in bulk having a vapour pressure exceeding 280 kPa absolute at a temperature of 37,8 °C, and other substances listed in Table of Technical Requirements (Appendix 1).

Ships carrying liquefied gases in bulk<sup>2</sup> are in full measure covered by the requirements of Rules for the Equipment of Sea-Going Ships, Rules for the Cargo Handling Gear of Sea-Going Ships, Load Line Rules for Sea-Going Ships. Rules for the Classification and Construction of Sea-Going Ships<sup>3</sup> apply to LG carriers to the extent stipulated in the text of the LG Rules.

#### **1.2 Definitions and explanations.**

**1.2.1** The following definitions are used in the LG Rules.

**Upper flammable limit** means the concentration of a hydrocarbon gas in air above which there is insufficient air to support and propagate combustion.

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

**Gas-safe space** is a space other than a gas-dangerous space.

**LG carrier** is a ship designed for the carriage of liquefied gases and other products in bulk listed in the Table of Technical Requirements (Appendix 1).

**LG-dangerous space (including hazardous space)** is:

a space in the cargo area which is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition;

an enclosed space outside the cargo area through which any piping containing liquid or gaseous product passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapour into the atmosphere of that space;

a cargo containment system and cargo piping;

a hold space where cargo is carried in a cargo containment system not requiring a secondary barrier;

a space separated from a hold space, in which a cargo containment system requiring a secondary barrier is arranged, by a single gastight steel boundary;

a cargo pump-room and cargo compressor room;

a zone on the open deck, or semi-enclosed space on the open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to cargo pump-rooms and cargo compressor rooms;

the open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2,4 m above the weather deck;

a zone within 2,4 m of the outer surface of a cargo containment system where such surface is exposed to the weather;

an enclosed or semi-enclosed space in which pipes containing products are located. (A space which contains gas detection equipment specified in 6.3, Part VIII "Instrumentation and Automation Systems" and a space utilizing boil-off gas as fuel and complying with the requirements of Part VI "Systems and Piping" are not considered as gas-dangerous spaces);

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<sup>1</sup>Hereinafter referred to as "the LG Rules".

<sup>2</sup>Hereinafter referred to as "the LG carriers".

<sup>3</sup>Hereinafter referred to as "the Rules for the Classification".

a compartment for cargo hoses;

an enclosed or semi-enclosed space having a direct opening into any gas-dangerous space or zone.

**Cargo tank** is the liquid-tight shell designed to be the primary container of the cargo and includes all such containers whether or not associated with insulation or secondary barriers or both.

**Cargo area** is that part of the ship which contains the cargo containment system and cargo pump and compressor rooms and includes deck areas over the full length and breadth of the part of the ship over the above-mentioned spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forward most hold space are excluded from the cargo area.

**Cargo machinery spaces** are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine-room.

**Cargo service spaces** are spaces within the cargo area used for workshops, lockers and store-rooms of more than 2 m<sup>2</sup> in area.

**Cargo containment system** is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements.

**Cargoes** are products listed in the Table of Technical Requirements (Appendix 1) and carried in bulk by ships, which meet the LG Rules requirements.

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

**Accommodation spaces** — see 1.5.2, Part VI "Fire Protection" of the Rules for the Classification.

**Tank cover** is the protective structure intended to protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

**Closed loop sampling** is a cargo sampling system that minimizes the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling.

**Insulation space** is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.

**Cofferdam** is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

**Tank dome** is the upward extension of a portion of a cargo tank protruding through the weather deck or a tank cover.

**MARVS** is the maximum allowable relief valve setting of a cargo tank.

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

**Thermal oxidation method** is a system where the boil-off vapours are utilized as fuel for shipboard use or as a waste heat system subject to the provisions of Chapter 16 or a system not using the gas as fuel complying with the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk<sup>1</sup>.

**Lower flammable limit** means the concentration of a hydrocarbon gas in air below when it is impossible to support and propagate combustion.

**Primary barrier** is the inner element designed to contain cargo when the cargo containment system includes two boundaries.

**Vapour density** is the relative weight of vapour compared with the weight of an equivalent volume air at the same pressure and temperature.

**Cargo control room** is a space used in the control of cargo handling operations and complying with the requirements of Section 10, Part VI "Systems and Piping".

**Control stations** — see 1.5.1, Part VI "Fire Protection" of the Rules for the Classification.

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<sup>1</sup> Hereinafter referred to as "the Code".

**Gas consumer** is any unit within the ship using cargo vapour as a fuel.

**Void space** is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, fuel oil tank, cargo pump or compressor room, or any space in normal use by personnel.

**Regasification plant** means equipment used for regasification operation, e.g. supply pump, suction drum, regasification unit, heating medium system, collecting drum, export manifold and associated piping.

**Regasification system for heat transfer agent** means piping system for heat energy supply to obtain the set parameters of gas offloading.

**Service space** — see 1.5.3, Part VI "Fire Protection" of Rules for the Classification.

**LNG** is a liquefied natural gas primarily consisting of methane.

**LPG** is a liquefied petroleum gas, primarily consisting of hydrocarbons (mixtures of propane and butane in any combination), whose composition may include small amounts of other components like hydrogen sulphide or lead alkyls.

**Boiling point** is the temperature in Celsius degrees at which a product exhibits a vapour pressure equal to the atmospheric pressure.

**Hold space** is the space enclosed by the ship's structure in which a cargo containment system is situated. Where the secondary barrier is the part of the hull structure, it may be the boundary of the hold space.

**Turret compartments** are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high-pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.

**Gas combustion unit (GCU)** is a means of disposing excess cargo vapour by thermal oxidation.

**Regasification unit** means booster pump, vaporizer and associated piping.

## 2 CLASS NOTATION

### 2.1 Class notation of a ship.

**2.1.1** The character of classification and additional distinguishing marks are assigned in accordance with the requirements of 2.2, Part I "Classification" of the Rules for the Classification.

### 2.2 Descriptive notation in the class notation.

**2.2.1** The ships meeting the requirements of the Rules for the Classification and the LG Rules are assigned the descriptive notation: **gas carrier** added to the character of classification (see Section 2, Part I "Classification" of the Rules for the Classification).

**2.2.2** The descriptive notation is supplemented with the words: **type 1G, type 2G, type 2PG and type 3G**, depending on the extent, to which a ship meets the requirements of Part III "Stability. Subdivision. Freeboard", as well as on the location of cargo tanks relative to the ship's shell plating and on the extent to which ship's survival capability is ensured taking into account the biological hazard of cargoes permitted for carriage.

**2.2.3** If a LG carrier is intended for the carriage of one specific cargo only, the name of that cargo, e.g. a **type 2G (ethylene) gas carrier**, is additionally indicated in the class notation. In this case, the requirements imposed on the ship are to take into account the specific hazards associated with the carriage of that cargo.

**2.2.4** If a LG carrier is intended for the carriage of several specific cargoes, the requirements are specified proceeding from the combination of properties of the most dangerous cargoes carried.

**2.2.5** When cargo tanks contain products, for which a **type 1G** ship is required, neither flammable liquids having a flashpoint of 60 °C or less, nor flammable products listed in Appendix 1, shall be carried in tanks located within the protective zones described in 2.4.1 of Part II "Ship Arrangement".

**2.2.6** When cargo tanks contain products, for which a **type 2G/2PG** ship is required, the flammable liquids as described in 4.2.6, shall not be carried in tanks located within the protective zones described in 2.4.2 of Part II "Ship Arrangement".

**2.2.7** In each case, for cargo tanks loaded with products, for which a **type 1G** or **2G/2PG** ship is required, the restriction applies to the protective zones within the longitudinal extent of the hold spaces for those tanks.

**2.2.8** The flammable liquids and products described in 4.2.6 may be carried within these protective zones when the quantity of products retained in the cargo tanks, for which a **type 1G** or **2G/2PG** ship is required, is solely used for cooling, circulation or fuelling purposes.

**2.2.9** Where a ship is fitted with a regasification unit for cargo export to shore and provided the requirements of 3.22, Part VI "Systems and Piping" are met, the distinguishing mark **RGU (Regasification unit)** shall be added to the ship's class notation. In addition, the requirements of 2.2.5.5, Part VII "Electrical Equipment" and Part V "Fire Protection" shall be met.

**2.2.10** Where a ship is fitted with a reliquefaction unit for cargo vapours complying with 4.2, Part VI "Systems and Piping", the distinguishing mark **RLU (Reliquefaction unit)** shall be added to the ship's class notation. The documentation specified in 4.4 shall be submitted to confirm the fulfillment of the requirements applying to ships with the distinguishing mark **RLU**.

**2.2.11** Where a ship is fitted with a gas combustion unit complying with 4.3, Part VI "Systems and Piping", the distinguishing mark **GCU (Gas combustion unit)** shall be added to the ship's class notation.

### 3 CLASSIFICATION SURVEYS

**3.1** Initial and/or periodical surveys of gas carriers to assign and/or confirm the class are carried out in accordance with Section 8, Part III "Additional Surveys of Ships Depending on their Purpose and Hull Material" of the Rules for Classification Surveys of Ships in Service.

**3.2** The survey of a ship to issue the Certificate is carried out during the initial or periodical survey of the ship.

**3.3** Ship's annual surveys are carried out within 3 months before or after every anniversary date since the day of issue of the Certificate, and are intended to ascertain that equipment, fittings, arrangements and materials of the ship meet the relevant requirements of the LG Rules.

An appropriate entry on the surveys carried out is made in the Certificate.

### 4 PLAN APPROVAL DOCUMENTATION

**4.1** In addition to the technical documentation specified in Section 3, Part I "Classification" of the Rules for the Classification, the following technical documentation confirming fulfillment of the LG Rules shall be submitted to the Register<sup>1</sup>:

**.1** drawings and strength calculations of cargo tanks with their distances from side plating and the bottom specified (\*);

**.2** drawings of supports and other structures for securing of independent cargo tanks (\*);

**.3** drawings and diagrams of systems and piping for cargo specifying the components like compensators, flange joints, stop and regulating valves (\*);

**.4** drawings and descriptions of an inert gas generation plant (\*);

**.5** justification of fitness of fire-extinguishing media, fire detection and extinction system apparatus for cargoes carried, as well as the documents confirming the design time of fire extinction, the rate of fire-extinguishing media delivery and the stores of fire-extinguishing media on board (\*\*);

**.6** diagrams and calculations of the ventilation system of spaces in the cargo area and of other spaces to be accessible for cargo operations performance. The diagrams are to contain data on fitness of materials used for manufacture of fan impellers and air ducts (\*);

**.7** diagrams and calculations of the vent system (\*);

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<sup>1</sup>Stamp types following the documentation (marked with (\*) and (\*\*)) review results according to 3.1.4, Part I «Classification» of the Rules for the Classification.

.8 drawings and descriptions of all systems and arrangements for the measurement of cargo amount and characteristics, and for gas detection (\*);

.9 diagrams and calculations of drain and ballast systems in the cargo area, pump-rooms, cofferdams, pipe tunnels, spaces for independent cargo tanks, etc. (\*);

.10 justification of fitness of insulating materials used in the cargo area, as well as data on the procedure of their manufacture, storage conditions, quality control techniques, the extent of a harmful effect of solar radiation, resistance to vibration and temperature (\*\*);

.11 drawings of quick-closing arrangements of the cargo containment system (\*);

.12 diagrams of cargo heating and refrigeration systems and the heat transfer calculation (\*);

.13 drawings of relief and vacuum relief valves of cargo tanks (\*);

.14 diagrams of cargo pressure and temperature regulation systems (\*);

.15 calculations of stresses in cargo and other piping containing cargo at a temperature below  $-110^{\circ}\text{C}$  (\*\*);

.16 diagrams of piping relating to the use of cargo as fuel with indication of separate units of pipe joints, and of valves location and design (\*);

.17 diagrams of electric drives and control systems for a reliquefaction unit for cargo vapours, liquefied gas refrigeration units, cargo pumps and compressors, an inertgas generation plant, fans of dangerous spaces and air locks and functional diagrams of control systems for units as above (\*);

.18 functional diagrams of electric measurement and alarm systems (\*);

.19 functional diagrams of systems for automatic and remote disconnection of electrical equipment, for remote control over hull structure heating valves (\*);

.20 drawings of cable laying in dangerous spaces and areas (\*);

.21 drawings of earthing for electrical equipment, cables, piping located in gas-dangerous spaces (\*);

.22 justification of electrical equipment fitness (\*\*);

.23 techniques for mechanical relief of stresses in independent cargo tanks (\*\*);

.24 Failure Mode and Effects analysis (FMEA) for electrical generation and distribution systems and associated control systems (refer to 2.1.4, Part VII "Electrical equipment") (\*\*);

.25 an inspection/survey plan for the cargo containment system (\*);

.26 cargo system operation manual in accordance with the requirements of Chapter 18 of the Code (\*).

4.2 General arrangement drawings or separate drawings are to demonstrate the layout of:

.1 cargo hatches (tank domes) and any other openings in cargo tanks;

.2 doors, hatches and any other openings into gas-dangerous spaces or zones (see 2.1, Part VII "Electrical Equipment");

.3 vent pipes and air inlet and outlet locations of a ventilation system;

.4 doors, scuttles, companions, ventilating duct outlets locations and other openings in spaces of the superstructure and spaces adjacent to the cargo area;

.5 assumed break-down of cargo tanks into groups for cargo separation.

4.3 The list of cargoes to be carried onboard a ship specifying their basic chemical and physical properties, as well as dangerous properties related to their carriage and storage, are to be submitted to the Register for consideration.

4.4 In addition to technical documentation specified in 4.1 the following technical documentation confirming that a ship complies with the requirements applying to ships with the distinguishing mark **RLU** and to a reliquefaction unit for cargo vapours shall be submitted to the Register prior to commencement of a ship's construction<sup>1</sup>:

.1 technical specification of reliquefaction unit for cargo vapours (\*\*);

.2 calculation of required capacity for reliquefaction unit for cargo vapours considering thermal flows for each cargo tank (\*\*);

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<sup>1</sup>Stamp types following the documentation (marked with (\*) and (\*\*)) review results according to 3.1.4, Part I «Classification» of the Rules for the Classification.



.3 arrangement plans of reliquefaction unit for cargo vapours and associated equipment (compressors, heat exchangers, pumps, pressure vessels, scrubbers) onboard with indication of escape routes from the compartment, where the unit is installed, and arrangement of permanently installed gas detection system (\*);

.4 arrangement plans for refrigerant, cooling medium and cooling water pipelines with indication of passing through the bulkheads, decks and platforms (\*);

.5 arrangement plans for electrical and automation equipment of reliquefaction unit for cargo vapours (\*);

.6 circuit diagrams of ventilation systems for compartments, where equipment for reliquefaction unit for cargo vapours is arranged, with indication of watertight and gastight bulkheads and fire-proof divisions, as well as the number of air changes per hour (\*);

.7 circuit diagrams of refrigerant, cooling medium and cooling water systems with indication of heat-transfer properties (\*);

.8 functional diagram and description of emergency shutdown system for reliquefaction unit for cargo vapours and its interaction with the emergency shutdown system for ship's cargo system (\*);

.9 list of mechanisms and equipment for reliquefaction unit for cargo vapours with indication of their technical characteristics (\*\*);

.10 list of electrical and automation equipment for reliquefaction unit for cargo vapours with indication of type of explosion protection and summary technical specification for the equipment (\*\*);

.11 failure mode and effects analysis (FMEA) for reliquefaction unit for cargo vapours (in accordance with IEC 60812 standard) performed against the level confirming the operation of the unit as intended after any single failure (\*\*);

.12 testing procedures during sea and gas trials of reliquefaction unit for cargo vapours (\*).

#### **4.5 "Approval in Principle" and "General Approval for Ship Application" of membrane LNG containment tanks.**

**4.5.1** The service "Approval in Principle" of membrane LNG containment tanks is rendered in accordance with 3.6, Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

**4.5.2** For the service "General Approval for Ship Application" of membrane LNG containment tanks to be rendered, the following technical documentation<sup>1,2</sup> shall be submitted to the Register for review:

.1 general information on ship in scope necessary to assess compliance of elements of membrane LNG tanks to applied requirements;

.2 general information on tanks geometrical dimensions and location in the ship's hull;

.3 drawings of tank structures of flat and corner regions, attachments to adjacent hull structures and cargo tank dome regions;

.4 drawings of pump tower including relevant equipment (pumps, pipelines, ladders, etc.) as well as its connection to ship's hull;

.5 drawings of pump tower base support;

.6 description of joining processes to connect tank elements to each other as well as connections with adjacent hull structures;

.7 list of materials and components used in tank structures and their test results;

.8 temperature calculations of tank elements and adjacent hull structures including description of applied calculation procedures;

.9 strength calculations of elements of membrane containment system including description of applied calculation procedures;

.10 calculation of ship's seakeeping and loads on the elements of membrane tank with description of applied calculation procedures and results of laboratory tests.

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<sup>1</sup>The Register may require additional information necessary to render service "General Approval for Ship Application".

<sup>2</sup>The results of rendered service "General Approval for Ship Application" are finalized by drawing up a conclusion letter (expert opinion) according to 8.5, Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

## **PART II. SHIP ARRANGEMENT**

### **1 GENERAL**

**1.1** The ship with a machinery installation arranged aft is taken as the basic type of a LG carrier.

**1.2** Hold spaces and turret compartments are to be separated from ship's spaces in accordance with the requirements of 2.3, Part V "Fire Protection".

**1.3** The ships having cargo tanks with the secondary barrier, which are designed for the carriage of cargoes at a temperature below  $-10\text{ }^{\circ}\text{C}$ , are to have a double bottom over the entire length of the cargo area, and also longitudinal bulkheads forming side tanks where cargo tanks fitted are intended for the carriage of cargoes at a temperature  $-55\text{ }^{\circ}\text{C}$  and below.

**1.4** Arrangements ensuring a seal between a deck and cargo tanks are to be provided in places where cargo tanks get through the weather deck.

**1.5** Control stations, accommodation and service spaces are not to be arranged within the cargo area.

In ships having cargo tanks with a secondary barrier, gastightness of accommodation and service spaces and control station bulkheads facing the cargo area is to be ensured.

**1.6** Entrances and openings into control stations, machinery, accommodation and service spaces are not to face the cargo area, forward and aft cargo-handling arrangements. These may be made in the bulkhead not facing the cargo area, forward and aft cargo-handling arrangements, and/or in side walls of superstructures or deckhouses at a distance of  $L/25$ , but at least 3 m, from the superstructure or deckhouse end. That distance may not exceed 5 m.

Wheelhouse doors may be installed within the specified limits if their design ensures quick closing and reliable wheelhouse gastightness.

**1.7** Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses shall comply with the requirements of 2.1.1, Part V "Fire Protection".

**1.8** The design of a hold space is to ensure the visual inspection of insulation as viewed from the hold space.

Where insulation integrity can be checked by the visual inspection of the bulkhead, separating the hold space, at the operational temperature of a cargo tank, the insulation inspection from the hold space is not required.

**1.9** The visual inspection is to be ensured at least on one side of the inner hull structure without removal of some permanent structure or equipment.

Where such inspection is possible on the outside of the inner hull only, the inner hull is not to be a fuel-oil tank boundary wall.

**1.10** Arrangements for hold spaces, void spaces, cargo tanks and other spaces classified as hazardous areas, shall be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and shall also allow for the evacuation of injured and/or unconscious personnel.

**1.11** Access to all cargo tanks shall be direct from the weather deck.

**1.12** The dimensions providing access through horizontal openings, hatches or manholes shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be not less than  $600 \times 600\text{ mm}$  with an angular radius up to maximum 100 mm. To reduce the stresses in way of the radius, the opening may be increased up to  $600 \times 800\text{ mm}$  with the radius increased up to 300 mm (refer to Fig. 1.12).

**1.13** The minimum vertical openings or manholes providing passage through the length and breadth of the space shall be not less than  $600 \times 800\text{ mm}$  with an angular radius 300 mm. When due to the structural strength of girders in double bottom tanks an opening 800 mm in height is not allowed, the opening  $600 \times 800\text{ mm}$  may be used (refer to Fig. 1.13).

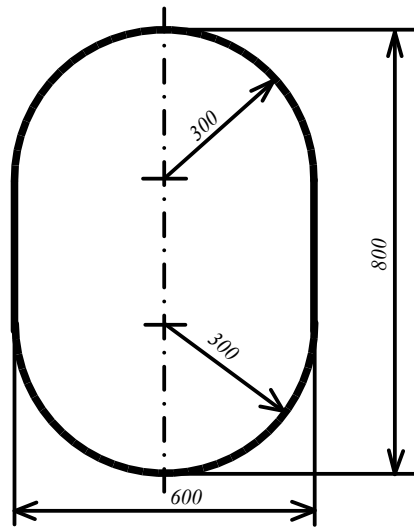


Fig. 1.12

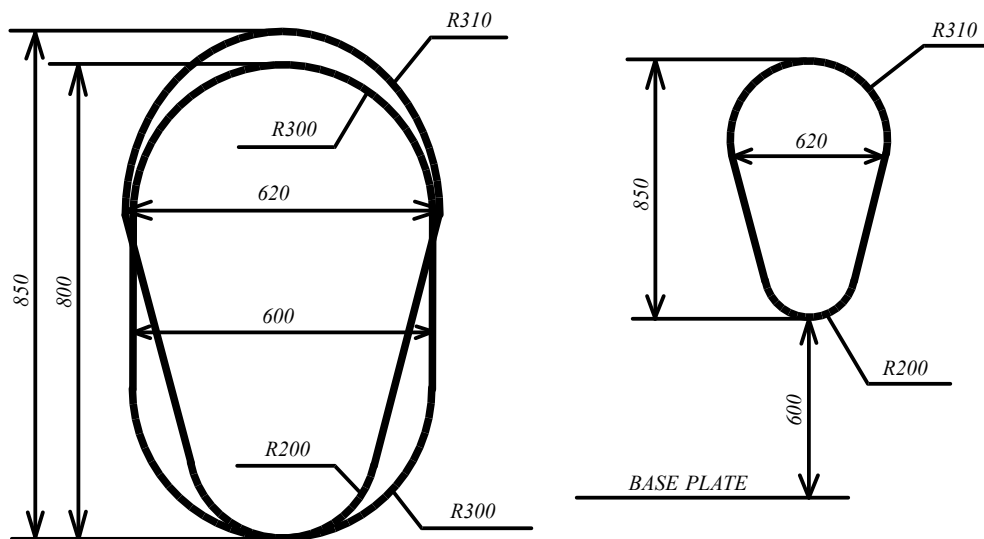


Fig. 1.13

For impeded evacuation of an injured person on the stretchers, the vertical opening may be used not less than  $850 \times 620$  mm (refer to Fig. 1.13) as an alternative to an opening  $600 \times 800$  mm with an angular radius 300 mm.

When the vertical opening is located at a height more than 600 mm, gratings and footholds shall be provided. In this case impeded evacuation of an injured person shall be demonstrated.

**1.14** Circular access openings to type C tanks shall have a diameter of not less than 600 mm.

**1.15** The dimensions referred to in 1.12 and 1.13 may be decreased, if the requirements of 1.10 can be met to the satisfaction of the Administration.

**1.16** Where cargo is carried in a containment system requiring a secondary barrier, the requirements of 1.12 and 1.13 do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non-hazardous area.

**1.17** Access required for inspection shall be a designated access through structures below and above cargo tanks, which shall have at least the cross-sections as required by 1.13.

**1.18** For the purpose of 1.8 or 1.9 the following shall apply:

**.1** where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface (e.g. for a type C tank), or 600 mm for a flat tank surface (e.g. for a type A tank) (refer to Fig. 1.18.1);

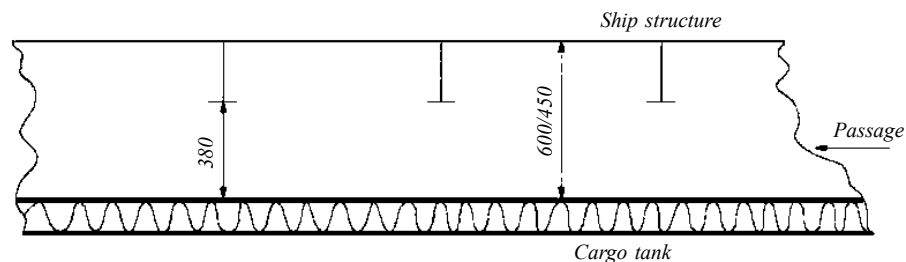


Fig. 1.18.1

**.2** where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (refer to Fig. 1.18.2);

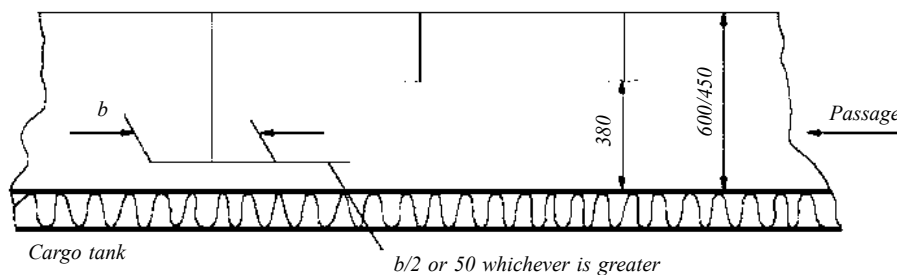


Fig. 1.18.2

**.3** if for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm (refer to Fig. 1.18.3). Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface;

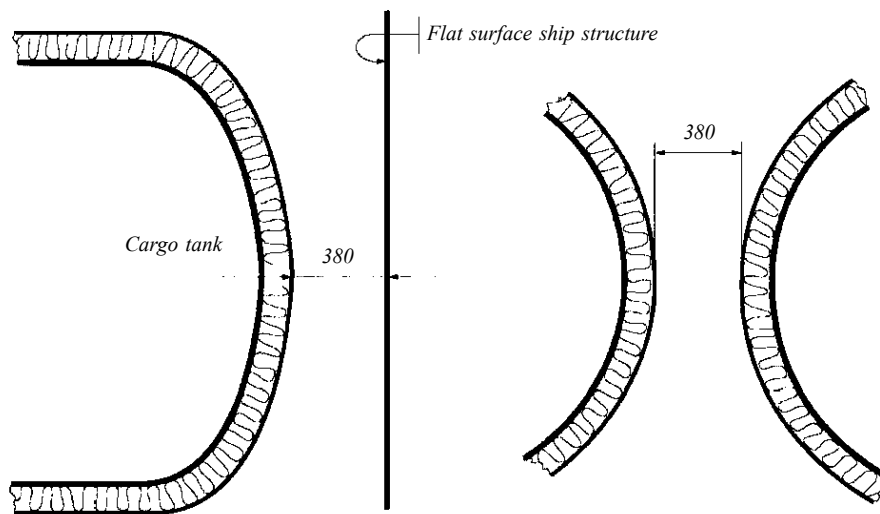


Fig. 1.18.3

.4 if for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted, a clearance of at least 450 mm shall be provided for access (refer to Fig. 1.18.4);

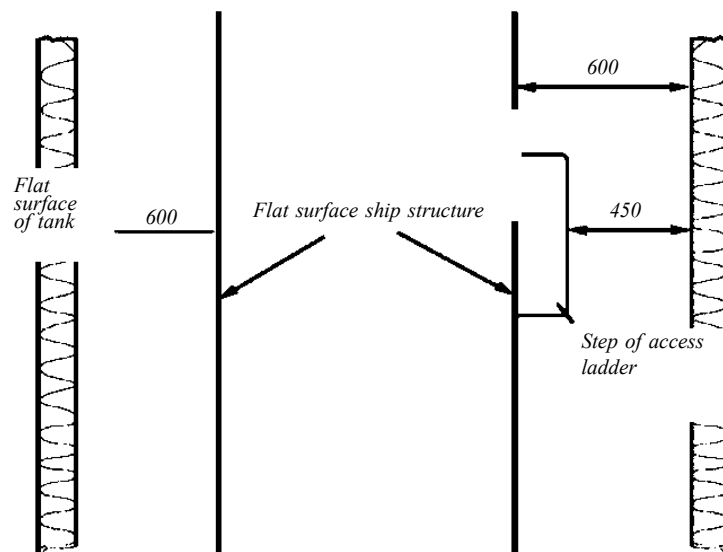


Fig. 1.18.4

.5 the minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in Fig. 1.18.5 (Fig. shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm). If there is no suction well, the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm;

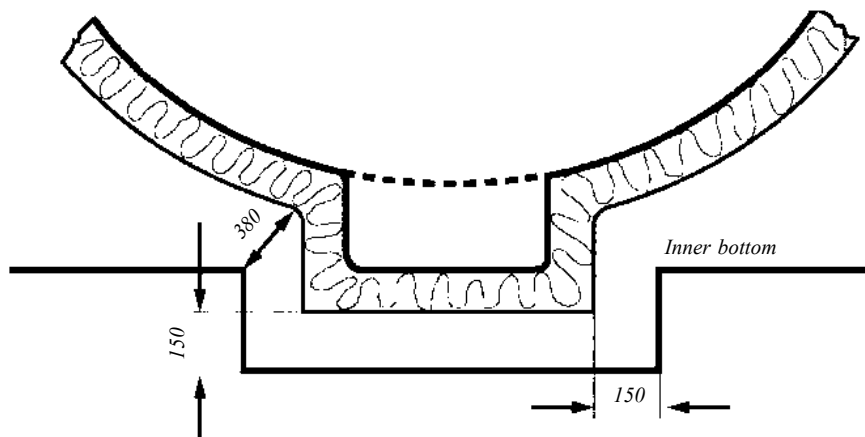


Fig. 1.18.5

.6 the distance between a cargo tank dome and deck structures shall not be less than 150 mm (refer to Fig. 1.18.6);

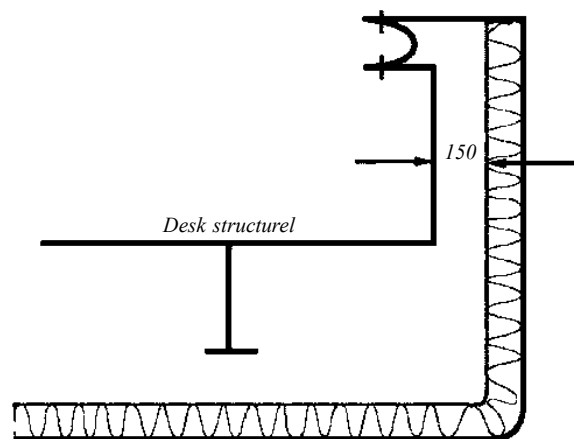


Fig. 1.18.6

.7 fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints (e.g. anti-pitching, anti-rolling and anti-flotation chocks), cargo tank insulation etc. This staging shall not impair the clearances specified in 1.18.1 — 1.18.4; and

.8 if fixed or portable ventilation ducting shall be fitted, such ducting shall not impair the distances required under 1.18.1 — 1.18.4.

1.19 Access to the space separated by a single gastight steel boundary from the hold space containing cargo tanks with a secondary barrier is to be provided from the open weather deck only.

1.20 To ensure access from a gas-dangerous space to a gas-safe space, provision shall be made for an air lock formed by two self-closing gastight steel doors spaced at least 1,5 m but not more than 2,5 m apart. Air lock door coamings shall be at least 300 mm high.

The requirements for alarm, electrical equipment, ventilation and cargo vapour presence monitoring are specified in 8.3.3, Part VI "Systems and Piping", in Part VII "Electrical Equipment" and in Section 6, Part VIII "Instrumentation and Automation Systems".

For the purpose of application of these Rules, watertight door may be considered as gastight.

**1.21** Where an air lock is not provided, access from the open weather deck to gas-dangerous spaces is to be arranged within a gas-safe zone at least 2,4 m above the weather deck.

**1.22** Pipe tunnels are to have at least two independent exits, leading to the open deck, arranged in opposite ends of the tunnel.

Exits in forward spaces or void spaces of the cargo area may be arranged in opposite ends of the tunnel. These exits are to be fitted with closures of the type approved by the Register.

**1.23** The dimensions and design of pipe tunnels are to make possible the unimpeded inspection and repair of piping, as well as the unimpeded evacuation of unconscious personnel in the event of injury.

**1.24** The design of covers for tank domes shall be approved by the Register.

**1.25** Arrangement of solid ballast in way of cargo tanks is generally not permitted. In special cases when taking in the solid ballast in way of cargo tanks is inevitable, this ballast is to be arranged so that impact loads in case of bottom damage are not transmitted directly to the cargo tanks.

## 2 STRUCTURAL PROTECTION TYPES. LOCATION OF CARGO TANKS

**2.1** The following standards of structural protection are provided for LG carriers.

**Type 1G** is the highest standard of structural protection in the transportation of products specified in the Table of Technical Requirements (Appendix 1) which are the most hazardous for the human and environment, and require maximum preventive measures to preclude the escape of such cargo.

**Type 2G** is a standard of structural protection in the transportation of less dangerous products specified in the Table of Technical Requirements (Appendix 1) which require significant preventive measures to preclude the escape of such cargo.

**Type 2PG** is a standard of structural protection for ships of 150 m in length and less in the transportation of dangerous products specified in the Table of Technical Requirements (Appendix 1) which require significant preventive measures to preclude the escape of such cargo, and where the products are to be carried in independent type C tanks designed for MARVS of at least 0,7 MPa gauge and a cargo containment system design temperature of  $-55^{\circ}\text{C}$  or above. The ship meeting these requirements, but having over 150 m in length is to be considered a **type 2G** ship.

**Type 3G** is a standard of structural protection in the transportation of products specified in the Table of Technical Requirements (Appendix 1) which require moderate preventive measures to preclude the escape of such cargo.

**2.2** The type of structural protection required in the transportation of individual products is specified in the Table of Technical Requirements (Appendix 1).

**2.3** When several products with a different degree of hazard are carried, the requirements for ship's damage trim and stability are to correspond to those for ships carrying the most dangerous of products carried.

**2.4** Cargo tanks shall be located at the following distances inboard:

**.1 type 1G ships:** from the moulded line of the outer shell, not less than the transverse extent of damage specified in 3.2.1.2, Part V "Subdivision" of the Rules for the Classification and, from the moulded line of the bottom shell at centreline, not less than the vertical extent of damage specified in 3.4.6.2, Part V "Subdivision" of the Rules for the Classification, and nowhere less than  $d$  where  $d$  is as follows (refer to Figs. 2.4.1-1 and 2.4.1-2):

**.1.1** for below or equal  $1000\text{ m}^3$ :  $d = 0,8\text{ m}$ ;

**.1.2** for  $1000\text{ m}^3 < V_c < 5000\text{ m}^3$ :  $d = 0,75 + V_c \times 0,2/4000\text{ m}$ ;

**.1.3** for  $5000\text{ m}^3 \leq V_c < 30000\text{ m}^3$ :  $d = 0,8 + V_c/25000\text{ m}$ ; and

**.1.4** for  $V_c \geq 30000\text{ m}^3$ :  $d = 2\text{ m}$

where  $V_c$  corresponds to 100 % of the gross design volume of the individual cargo tank at  $20^{\circ}\text{C}$ , including domes and appendages. For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s); and

$d$  is measured at any cross section at a right angle from the moulded line of outer shell.

Tank size limitations may apply to **type 1G** ship cargoes in accordance with Part X "Special Requirements";

**.2 types 2G/2PG:** from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in 3.4.6.2, Part V "Subdivision" of the Rules for the Classification, and nowhere less than  $d$  as indicated in 2.4.1.1 (refer to Figs. 2.4.1-1 and 2.4.2);

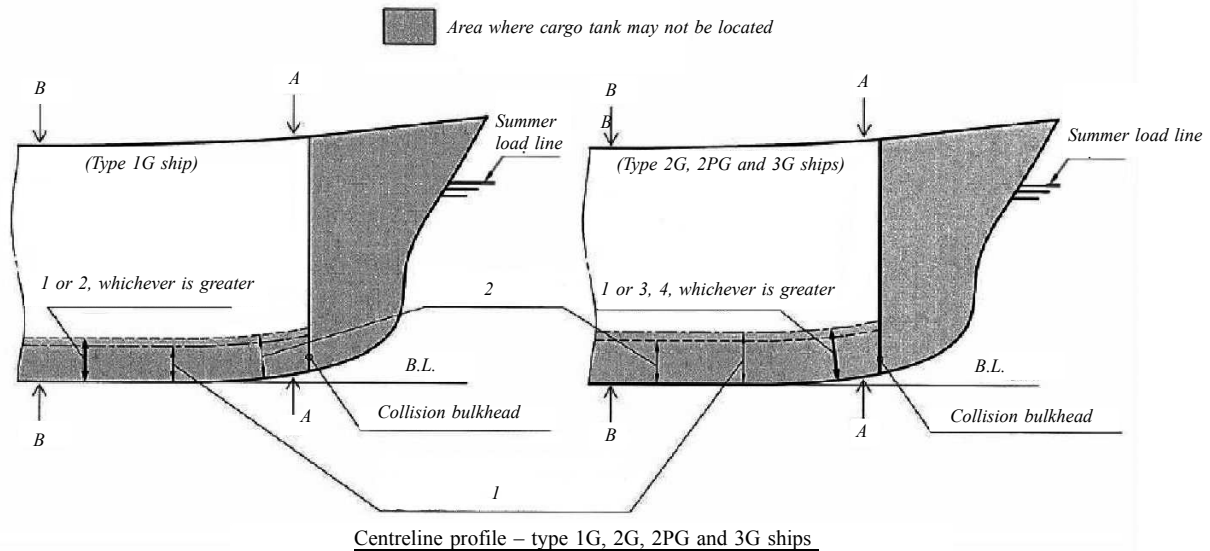


Fig. 2.4.1-1

Cargo tank location requirements for **type 1G, 2G, 2PG and 3G** ships:

- 1 — vertical extent of bottom damage specified in 3.4.6.2, Part V "Subdivision" of the Rules for the Classification; 2 — distance  $d$  specified in 2.4.1.1, Part II "Ship Arrangement" of the LG Rules; 3 — distance  $d$  specified in 2.4.1.2, Part II "Ship Arrangement" of the LG Rules; 4 — distance  $d$  specified in 2.4.1.3, Part II "Ship Arrangement" of the LG Rules; 5 — transverse extent measured in board of ship side specified in 3.2.1.2, Part V "Subdivision" of the Rules for the Classification

**.3 type 3G ships:** from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in 3.4.6.2, Part V "Subdivision" of the Rules for the Classification, and nowhere less than  $d$ , where  $d = 0,8$  m from the moulded line of outer shell (refer to Figs. 2.4.1-1 and 2.4-3).

**2.5** For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi-membrane tanks are used, otherwise to the bottom of the cargo tanks.

The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semimembrane tanks are used, otherwise to the side of the cargo tanks.

The distances indicated in 2.4 shall be applied as in Figs. 2.5-1 — 2.5-5. These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.

**2.6** Cargo tanks shall not be located forward of the collision bulkhead.

**2.7** Except the ships carrying products, which require the **type 1G** structural protection, suction wells of cargo tanks may protrude into the vertical extent of bottom damage, but their protrusion below the inner bottom plating is not to exceed 25 % of the double bottom depth or 350 mm, whichever is less. The wells meeting this requirement are ignored in determining the number of compartments flooded.

**2.8** The location requirements may be applied separately to each cargo tank depending on the degree of hazard of the product carried in it.

**2.9** The position of the moulded line for different containment systems is shown in Figs. 2.5-1 — 2.5-5.



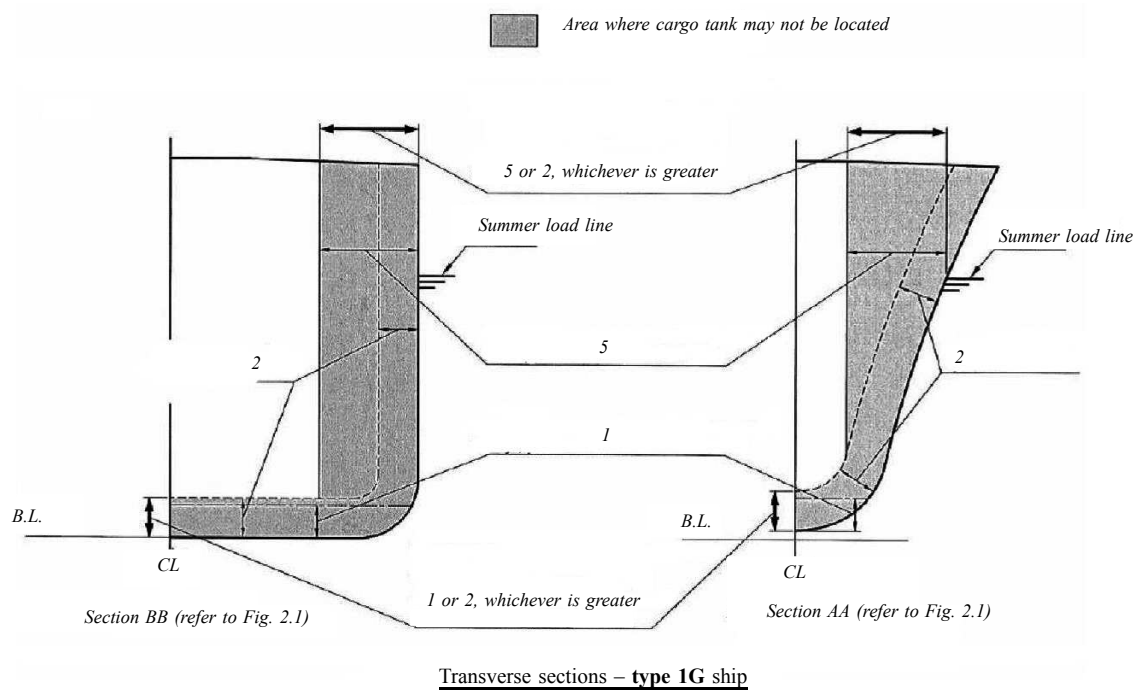


Fig. 2.4.1-2  
Cargo tank location requirements for **type 1G** ships:  
1 — 5 — refer to Fig. 2.4.1-1

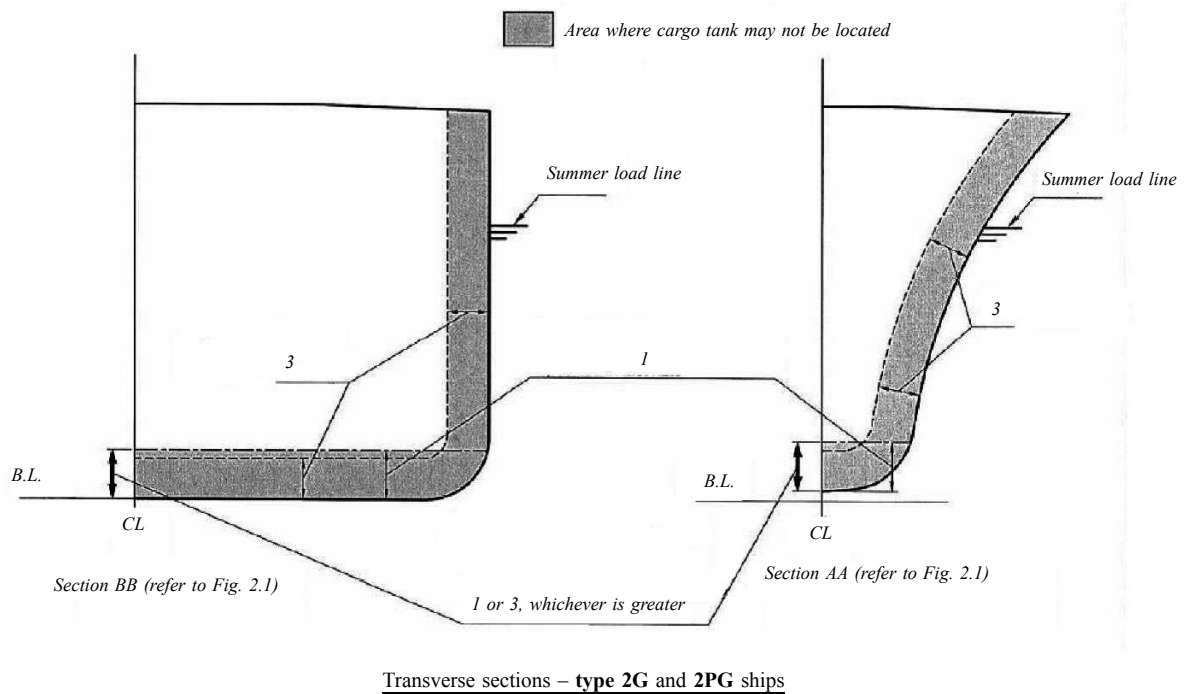


Fig. 2.4.2  
Cargo tank location requirements for **type 2G** and **2PG** ships:  
1, 3 — refer to Fig. 2.4.1-1

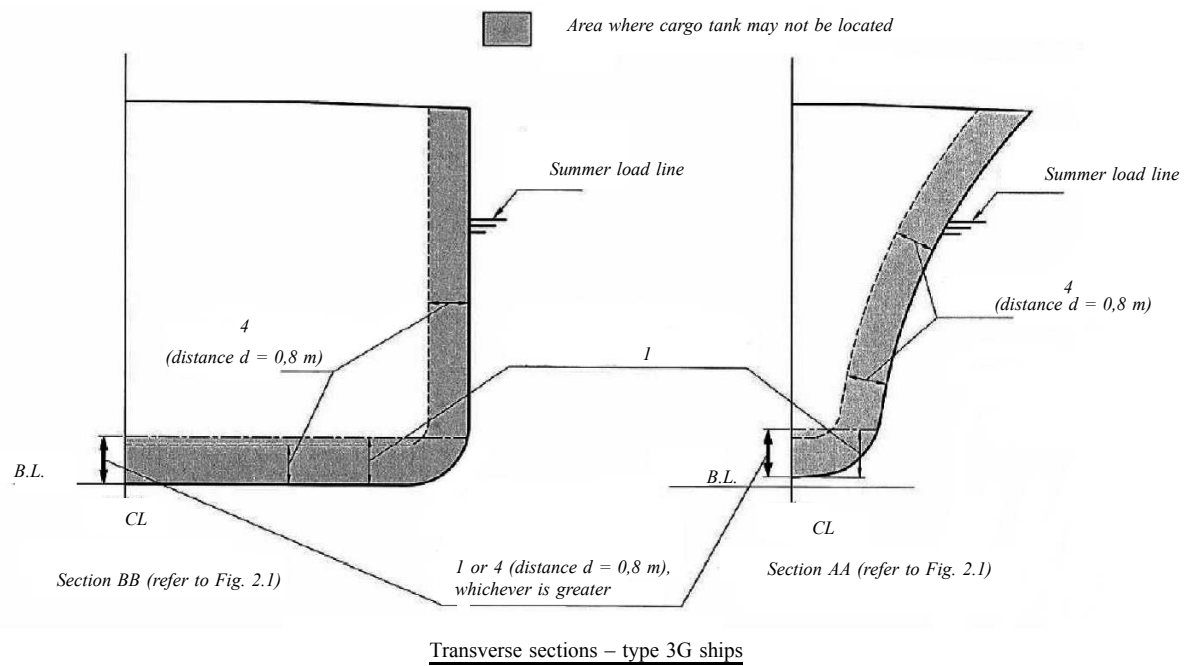


Fig. 2.4.3  
Cargo tank location requirements for **type 3G** ships:  
 $1, 4$  — refer to Fig. 2.4.1-1

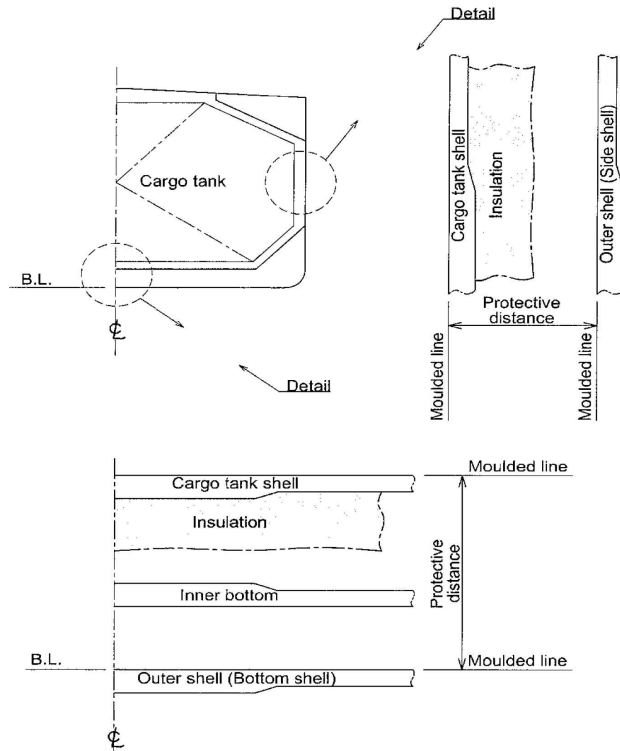


Fig. 2.5-1 Protective distance to independent prismatic tank

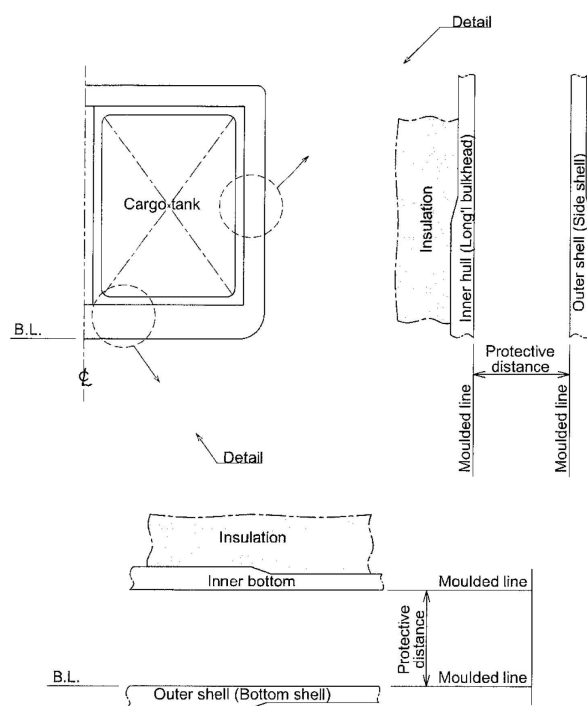


Fig. 2.5-2 Protective distance to semi-membrane tank

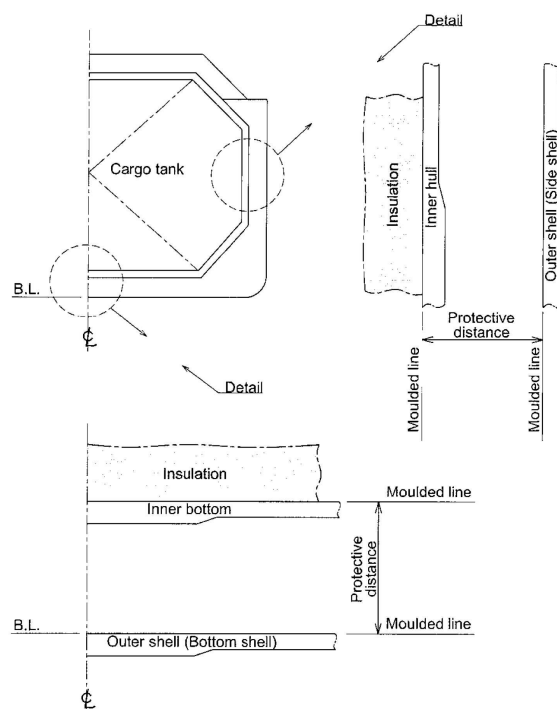


Fig. 2.5-3 Protective distance to membrane tank

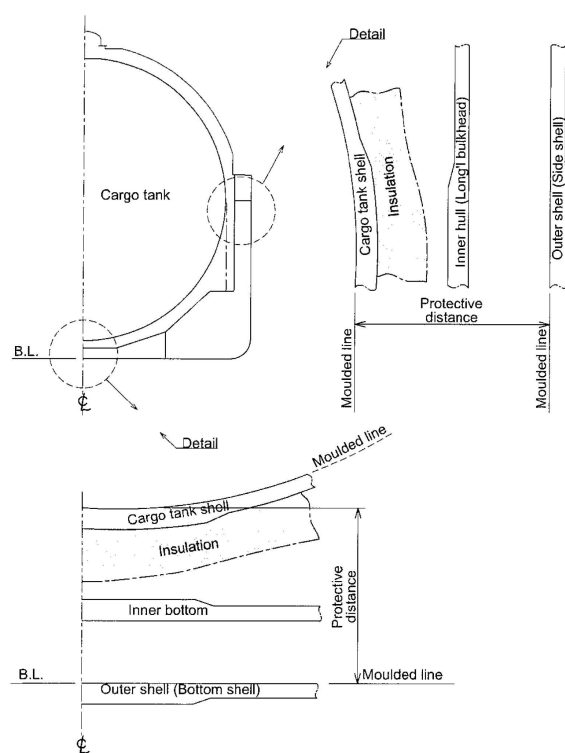


Fig. 2.5-4 Protective distance to spherical tank

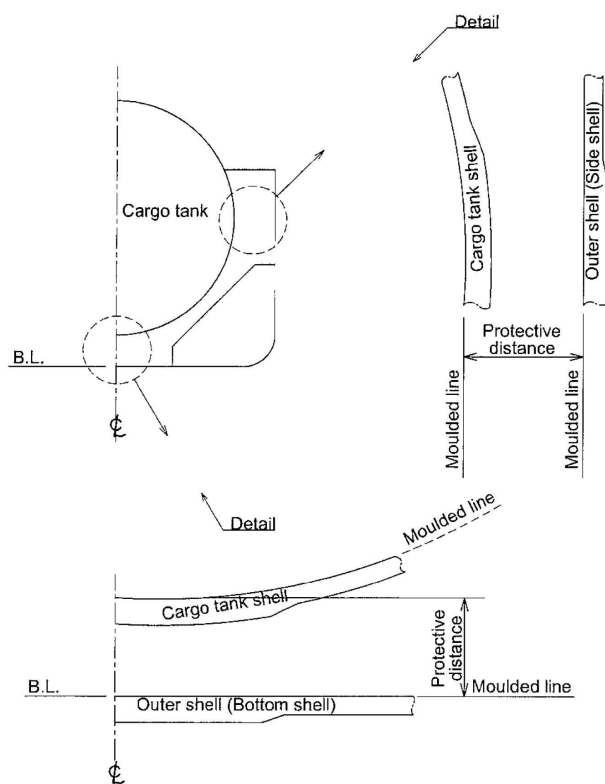
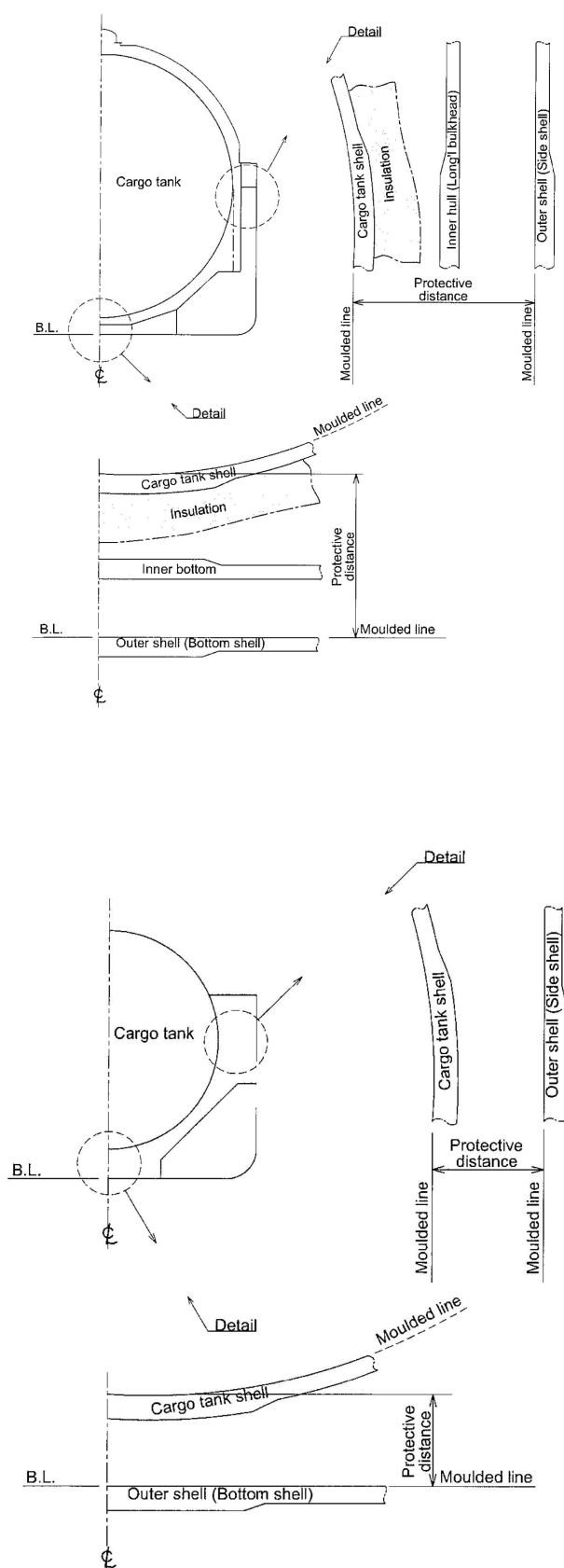


Fig. 2.5-5 Protective distance to pressure type tank



### **3 HULL**

**3.1** Dimensions of hull structural members are determined in accordance with the requirements for tankers and bulkers of the Rules for the Classification depending on the actual ship's structures arrangement and cargo tanks type.

**3.2** The requirements for the design and dimensions of cofferdams are specified in 2.7, Part II "Hull" of the Rules for the Classification.

## **PART III. STABILITY. SUBDIVISION. FREEBOARD**

### **1 STABILITY**

**1.1** The stability of gas carriers is to meet the requirements of Part IV "Stability" of the Rules for the Classification covering tankers and is to be verified for each type of cargo for loading conditions specified in 3.4, Part IV "Stability" of Rules for the Classification.

The free surface effect in cargo tanks is to be taken into account according to their actual filling with due regard for its potential change in voyage.

**1.2** During cargo operations a corrected metacentric height is to be at least 0,15 m. The calculations confirming fulfillment of this requirement are to be submitted as part of design documentation.

**1.3** In addition to the requirements of 1.4.11, Part IV "Stability" of the Rules for the Classification, the Stability Booklet is to include data on gas carrier stability during cargo operations and the instructions on the sequence of cargo tanks loading and unloading.

**1.4** Every ship shall be fitted with a stability instrument, capable of verifying compliance with applicable intact and damage stability requirements, approved by the Register.

### **2 DAMAGE STABILITY WITH LOCAL DAMAGES**

**2.1** The requirements of 3.3, Part V «Subdivision» of the Rules for the Classification shall be met at local damage anywhere in the cargo area. The damage extent shall be assumed not less than distance  $d$  calculated according to 2.4, Part "Ship Arrangement" and measured normal to the moulded line of the outer shell.

Number of flooded compartments shall be assumed according to 3.4.6, Part V "Subdivision" of the Rules for the Classification.

### **3 SUBDIVISION**

**3.1** All ships are to meet the requirements of Part V "Subdivision" of the Rules for the Classification.

**3.2** The main transverse bulkhead may have a recess provided that all recess parts are located between the vertical planes which are inside the hull at a distance of  $B/5$  from the shell plating measured at right angles to the centerline at the level of the ship's subdivision load line.

Any part of the recess outside the above limits is to be considered as a step.

**3.3** The ship is to be so designed as to keep the probability of unsymmetrical flooding to a minimum.

Valves (slide valves) and cross-flooding pipes are not to be taken into account in damage trim and stability calculations. The exception concerns calculations of the ship's equalization time only.

The spaces linked by cross-flooding ducts of large cross-sectional area may be considered to be common.

**3.4** If pipes, ducts and tunnels are situated within the extent of damage penetration defined in 3.2, Part V "Subdivision" of the Rules for the Classification, provision is to be made for arrangements preventing ship's progressive flooding. The exception concerns the spaces whose flooding is considered in damage trim and stability calculations.

**3.5** The angle of heel in the final stage of flooding is not to exceed the angle wherein the emergency source of power may still be capable of operating.

#### **4 FREEBOARD**

**4.1** The minimum freeboard for LG carriers is assigned in accordance with the Load Line Rules for Sea-Going Ships.

The assigned freeboard is not to be less than that wherein the requirements of the present Part are met.



## **PART IV. CARGO CONTAINMENT**

### **1 GENERAL**

**1.1** The goal of requirements specified in this Part is to ensure the safe containment of cargo under all design and operating conditions having regard to the nature of the cargo carried. This will include measures to:

- provide strength to withstand defined loads;
- maintain the cargo in a liquid state;
- design for or protect the hull structure from low temperature exposure, and
- prevent the ingress of water or air into the cargo containment system.

#### **1.2 Definitions and explanations.**

**1.2.1** In addition to the definitions in 1.2, Part I "Classification", the definitions given in this Section shall apply throughout this Part.

**I n d e p e n d e n t t a n k s** are self-supporting tanks. They do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tank, which are referred to in Sections 21 — 23.

**I n t e g r a l t a n k s** are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in Section 25.

**W o h l e r (  $S - N$  ) c u r v e**<sup>1</sup> is a stress-cycle number dependence diagram where the fatigue material damage occurs at the given stress cycle number.

**M e m b r a n e t a n k s** are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in Section 24.

**S e m i - m e m b r a n e t a n k s** are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure. Semi-membrane tanks are covered in Section 26.

**D e s i g n t e m p e r a t u r e f o r s e l e c t i o n o f m a t e r i a l s** is the minimum temperature at which cargo may be loaded or transported in the cargo tanks.

**D e s i g n v a p o u r p r e s s u r e  $P_0$**  is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

**A c o l d s p o t** is a part of the hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/temperature control systems required in Section 4, Part VI "Systems and Piping".

### **2 APPLICATION**

**2.1** Unless otherwise specified in Sections 21 — 26, the requirements of Sections 1 — 20 shall apply to all types of tanks, including those covered in Section 27.

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<sup>1</sup>Additional provisions not included in the Code.

### **3 FUNCTIONAL REQUIREMENTS FOR CARGO CONTAINMENT**

**3.1** The design life of the cargo containment system shall not be less than the design life of the ship.

**3.2** Cargo containment systems shall be designed for North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Lesser environmental conditions, consistent with the expected usage, may be accepted according to a procedure agreed with the Register for cargo containment systems used exclusively for restricted navigation. Greater environmental conditions may be required for cargo containment systems operated in conditions more severe than the North Atlantic environment.

**3.3** Cargo containment systems shall be designed with suitable safety margins:

**.1** to withstand, in the intact condition, the environmental conditions anticipated for the cargo containment system's design life and the loading conditions appropriate for them, which include full homogeneous and partial load conditions, partial filling within defined limits and ballast voyage loads; and

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

**3.4** The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions which shall be considered for the design of each cargo containment system are given in Sections 21 — 26. There are three main categories of design conditions:

**.1** ultimate design conditions — the cargo containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

internal pressure;

external pressure;

dynamic loads due to the motion of the ship;

thermal loads;

sloshing loads;

loads corresponding to ship deflections;

tank and cargo weight with the corresponding reaction in way of supports;

insulation weight;

loads in way of towers and other attachments; and

test loads.

**.2** fatigue design conditions — the cargo containment system structure and its structural components shall not fail under accumulated cyclic loading;

**.3** the cargo containment system shall meet the following criteria.

Collision — the cargo containment system shall be protectively located in accordance with 2.4, Part II "Ship Arrangement", and withstand the collision loads specified in 15.1 without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.

Fire — the cargo containment systems shall sustain, without rupture, the rise in internal pressure specified in 3.19.1, Part VI "Systems and Piping", under the fire scenarios envisaged therein.

Flooded compartment causing buoyancy on tank — the anti-flotation arrangements shall sustain the upward force, specified in 15.2, and there shall be no endangering plastic deformation to the hull.

**3.5** Measures shall be applied to ensure that scantlings required meet the structural strength provisions and be maintained throughout the design life. Measures may include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting. Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature, a suitable corrosion allowance shall be applied and agreed with the Register.

**3.6** An inspection/survey plan for the cargo containment system shall be approved by the Register. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo

containment system's life and, in particular, all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment, shall be designed and built to ensure safety during operations, inspection and maintenance (refer to Section 1, Part II "Ship Arrangement").

#### 4 CARGO CONTAINMENT SAFETY PRINCIPLES

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

**4.2** The size and configuration or arrangement of the secondary barrier may be reduced where an equivalent level of safety is demonstrated in accordance with the requirements of 4.3 — 4.5, as applicable.

**4.3** Cargo containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low, but where the possibility of leakages through the primary barrier cannot be excluded, shall be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages. The arrangements shall comply with the following requirements:

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

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

**4.4** No secondary barrier is required for cargo 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.

**4.5** No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above  $-10^{\circ}\text{C}$ .

#### 5 SECONDARY BARRIERS IN RELATION TO TANK TYPES

**5.1** Secondary barriers in relation to the tank types defined in Sections 21 — 26 shall be provided in accordance with the Table 5.1.

Table 5.1

Cargo temperature at atmospheric pressure	$-10^{\circ}\text{C}$ and above	Below $-10^{\circ}\text{C}$ down to $-55^{\circ}\text{C}$	Below $-55^{\circ}\text{C}$
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral Membrane Semi-membrane Independent: type A type B type C		Tank type not normally allowed <sup>1</sup> Complete secondary barrier Complete secondary barrier <sup>2</sup>  Complete secondary barrier Partial secondary barrier No secondary barrier required	

<sup>1</sup>A complete secondary barrier shall normally be required if cargoes with a temperature at atmospheric pressure below  $-10^{\circ}\text{C}$  are permitted in accordance with 25.1.

<sup>2</sup> In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, a partial secondary barrier may be accepted.

## **6 DESIGN OF SECONDARY BARRIERS**

**6.1** Where the cargo temperature at atmospheric pressure is not below  $-55^{\circ}\text{C}$ , the hull structure may act as a secondary barrier based on the following:

**.1** the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by 19.2.4; and

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

**6.2** The design of the secondary barrier shall be such that:

**.1** it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 18.3.6;

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

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

**.4** it is capable of being periodically checked for its effectiveness by means acceptable to the Register. This may be by means of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with the Register;

**.5** the methods required in 6.2.4 above shall be approved by the Register and shall include, where applicable to the test procedure:

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

accuracy and range of values of the proposed method for detecting defects specified above;

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

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

**.6** the secondary barrier shall fulfil its functional requirements at a static angle of heel of  $30^{\circ}$ .

## **7 PARTIAL SECONDARY BARRIERS AND PRIMARY BARRIER SMALL LEAK PROTECTION SYSTEM**

**7.1** Partial secondary barriers as permitted in 4.3 shall be used with a small leak protection system and meet all the requirements in 6.2. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

**7.2** The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in 18.3.6, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

**7.3** 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.

## **8 SUPPORTING ARRANGEMENTS**

**8.1** The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in Sections 12 — 15, 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.

**8.2** Anti-flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in 15.2 without plastic deformation likely to endanger the hull structure.

**8.3** Supports and supporting arrangements shall withstand the loads defined in 13.9 and Section 15, but these loads need not be combined with each other or with wave-induced loads.

## **9 ASSOCIATED STRUCTURE AND EQUIPMENT**

**9.1** Cargo containment systems shall be designed for the loads imposed by associated structure and equipment. This includes pump towers, cargo domes, cargo 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).

## **10 THERMAL INSULATION**

**10.1** Thermal insulation shall be provided, as required, to protect the hull from temperatures below those allowable (refer to 19.2) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Section 4, Part VI "Systems and Piping".

**10.2** In determining the insulation performance, due regard shall be given to the amount of the acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.

## **11 DESIGN LOADS. GENERAL**

**11.1** This Section and Sections 12 — 15 define the design loads to be considered with regard to the requirements in Sections 16 — 18. These include:

load categories (permanent, functional, environmental and accidental) and the description of the loads; the extent to which these loads shall be considered depending on the type of tank, and is more fully detailed in the following paragraphs; and

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

## **12 PERMANENT LOADS**

### **12.1 Gravity loads.**

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

### **12.2 Permanent external loads.**

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

### 13 FUNCTIONAL LOADS

**13.1** Loads arising from the operational use of the tank system shall be classified as functional loads. All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered. As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

- internal pressure;
- external pressure;
- thermally induced loads;
- vibration;
- interaction loads;
- loads associated with construction and installation;
- test loads;
- static heel loads; and
- weight of cargo.

#### **13.2 Internal pressure.**

**13.2.1** In all cases, including 13.2.2,  $P_0$  shall not be less than MARVS.

**13.2.2** For cargo tanks, where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature,  $P_0$  shall not be less than the gauge vapour pressure of the cargo at a temperature of 45 °C except as follows:

**.1** lower values of ambient temperature shall be agreed with the Register for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required; and

**.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.

**13.2.3** Taking into account the calculations made in accordance with the agreed procedure and the limitations given in Sections 21 — 26, 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. Any relief valve setting resulting from this para shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

**13.2.4** The internal pressure  $P_{eq}$  results from the vapour pressure  $P_0$  or  $P_h$  plus the maximum associated dynamic liquid pressure  $P_{gd}$ , but not including the effects of liquid sloshing loads. Formula for associated dynamic liquid pressure  $P_{gd}$  is given in 28.1.

#### **13.3 External pressure.**

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

#### **13.4 Thermally induced loads.**

**13.4.1** Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below –55 °C.

**13.4.2** Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (refer to 4.1.3, Part VI "Systems and Piping").

#### **13.5 Vibration.**

**13.5.1** The potentially damaging effects of vibration on the cargo containment system shall be considered.

#### **13.6 Interaction loads.**

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

#### **13.7 Loads associated with construction and installation.**

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

**13.8 Test loads.**

**13.8.1** Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in Sections 21 — 26.

**13.9 Static heel loads.**

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

**13.10 Other loads.**

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

## **14 ENVIRONMENTAL LOADS**

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

**14.2 Loads due to ship motion.**

**14.2.1** The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading.

**14.2.2** The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:

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

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

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

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

**14.2.4** Formulae for acceleration components are given in 28.2.

**14.2.5** Loads for ships of restricted service may be specified in accordance with a procedure agreed with the Register.

**14.3 Dynamic interaction loads.**

**14.3.1** Account shall be taken of the dynamic component of loads resulting from interaction between cargo containment systems and the hull structure, including loads from associated structures and equipment.

**14.4 Sloshing loads.**

**14.4.1** The sloshing loads on a cargo containment system and internal components shall be evaluated based on allowable filling levels.

**14.4.2** When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

**14.5 Snow and ice loads.**

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

**14.6 Loads due to navigation in ice.**

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

## 15 ACCIDENTAL LOADS

**15.1** Accidental loads are defined as loads that are imposed on a cargo containment system and its supporting arrangements under abnormal and unplanned conditions.

### **15.2 Collision loads.**

**15.2.1** The collision load shall be determined based on the cargo containment system under fully loaded condition with an inertial force corresponding to 0,5g in the forward direction and 0,25g in the aft direction, where "g" is gravitational acceleration.

### **15.3 Loads due to flooding on ship.**

**15.3.1** For independent tanks, loads caused by the buoyancy of an empty tank in a hold space flooded to the summer load draught shall be considered in the design of the anti-flotation chocks and the supporting hull structure.

## 16 STRUCTURAL INTEGRITY. GENERAL

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

**16.2** The structural integrity of cargo containment systems shall be demonstrated by compliance with Sections 21 — 26, as appropriate, for the cargo containment system type.

**16.3** The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by Sections 21 — 26 shall be demonstrated by compliance with Section 27 to ensure that the overall level of safety provided in this Part of the Rules is maintained.

## 17 STRUCTURAL ANALYSES

### **17.1 Analysis.**

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

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

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

### **17.2 Load scenarios.**

**17.2.1** For each location or part of the cargo containment system to be considered and for each possible mode of failure to be analyzed, all relevant combinations of loads that may act simultaneously shall be considered.

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

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

$$\sigma_x = \sigma_{x,st} \pm \sqrt{\Sigma(\sigma_{x,dyn})^2}; \quad (17.2.3-1)$$

$$\sigma_y = \sigma_{y,st} \pm \sqrt{\Sigma(\sigma_{y,dyn})^2}; \quad (17.2.3-2)$$

$$\sigma_z = \sigma_{z,st} \pm \sqrt{\Sigma(\sigma_{z,dyn})^2}; \quad (17.2.3-3)$$



$$\tau_{xy} = \tau_{xy,st} \pm \sqrt{\Sigma(\tau_{xy,dyn})^2}; \quad (17.2.3-4)$$

$$\tau_{xz} = \tau_{xz,st} \pm \sqrt{\Sigma(\tau_{xz,dyn})^2}; \quad (17.2.3-5)$$

$$\tau_{yz} = \tau_{yz,st} \pm \sqrt{\Sigma(\tau_{yz,dyn})^2}; \quad (17.2.3-6)$$

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

$\sigma_{x,dyn}$ ,  $\sigma_{y,dyn}$ ,  $\sigma_{z,dyn}$ ,  $\tau_{xy,dyn}$ ,  $\tau_{xz,dyn}$ ,  $\tau_{yz,dyn}$  are dynamic stresses, determined separately from acceleration components and hull strain components due to deflection and torsion.

## 18 DESIGN CONDITIONS

**18.1** All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given above in this Part of the Rules, and the load scenarios are covered by 17.2.

### 18.2 Ultimate design condition.

**18.2.1** Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of these Rules.

**18.2.2** Plastic deformation and buckling shall be considered.

**18.2.3** Analysis shall be based on characteristic load values as follows:

permanent loads — expected values;

functional loads — specified values;

environmental loads — for wave loads: most probable largest load encountered during  $10^8$  wave encounters.

**18.2.4** For the purpose of ultimate strength assessment, the following material parameters apply:

**.1.1**  $R_e$  = specified minimum yield stress at room temperature, in MPa. If the stress-strain curve does not show a defined yield stress, the 0,2 % proof stress applies;

**.1.2**  $R_m$  = specified minimum tensile strength at room temperature, in MPa.

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

**.2** the above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. The enhanced yield stress and tensile strength at low temperature may be taken into account. The temperature on which the material properties are based shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

**18.2.5** The equivalent stress  $\sigma_C$  (von Mises, Huber) shall be determined by:

$$\sigma_C = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2)}, \quad (18.2.5)$$

where

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

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

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

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

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

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

The above values shall be calculated as described in 17.3.

**18.2.6** Allowable stresses for materials other than those covered by Part IX "Materials and Welding" shall be subject to approval by the Register.

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

**18.3 Fatigue design condition.**

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

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

$$\sum \frac{n_i}{N_i} + \frac{n_{\text{Loading}}}{N_{\text{Loading}}} \leq C_w \quad (18.3.2)$$

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;

$n_{\text{Loading}}$  = number of loading and unloading cycles during the life of the tank, not to be less than 1000 (normally corresponds to 20 years of operation). Loading and unloading cycles include a complete pressure and thermal cycle;

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

$C_w$  = maximum allowable cumulative fatigue damage ratio.

The fatigue damage shall be based on the design life of the tank but not less than  $10^8$  wave encounters.

**18.3.3** Where required, the cargo containment system shall be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the cargo containment system. Consideration shall be given to various filling conditions.

**18.3.4** Wohler ( $S - N$ ) curves application.

**18.3.4.1** Design  $S - N$  curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

**18.3.4.2** The  $S - N$  curves shall be based on a 97.6 % probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of  $S - N$  curves derived in a different way requires adjustments to the acceptable  $C_w$  values specified in 18.3.7 — 18.3.9.

**18.3.5** Analysis shall be based on characteristic load values as follows:

permanent loads — expected values;

functional loads — specified values or specified history;

environmental loads — expected load history, but not less than  $10^8$  cycles.

If simplified dynamic loading spectra are used for the estimation of the fatigue life, they shall be approved by the Register.

**18.3.6** Fatigue crack propagation analysis.

**18.3.6.1** Where the size of the secondary barrier is reduced, as is provided for in 4.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

.1 crack propagation paths in the structure;

.2 crack growth rate;

.3 the time required for a crack to propagate to cause a leakage from the tank;

.4 the size and shape of through thickness cracks; and

.5 the time required for detectable cracks to reach a critical state.

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

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

**18.3.6.3** Crack propagation analysis under the condition specified in 18.3.7: the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in Fig. 18.3.6.3. Load distribution and sequence for longer periods, such as in 18.3.8 and 18.3.9 shall be approved by the Register.

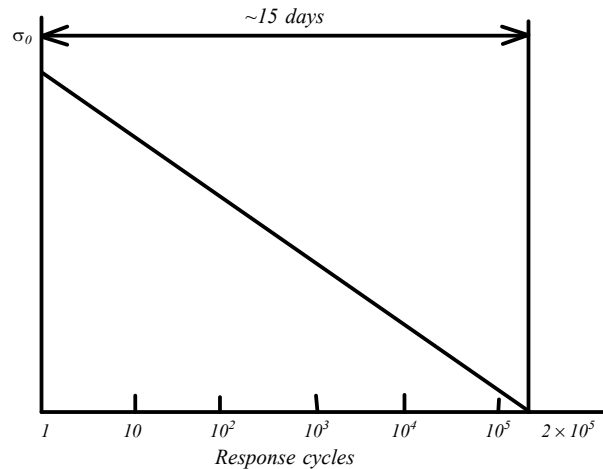


Fig. 18.3.6.3 Simplified load distribution  
( $\sigma_0$  = most probable maximum stress over the life of the ship.  
Response cycle scale is logarithmic. The value of  $2 \times 10^5$  is given as an example of estimate)

**18.3.6.4** The arrangements shall comply with 18.3.7 — 18.3.9, as applicable.

**18.3.7** For failures that can be reliably detected by means of leakage detection:

$C_w$  shall be less than or equal to 0,5.

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

**18.3.8** For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections,  $C_w$  shall be less than or equal to 0,5.

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

**18.3.9** In particular locations of the tank, where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum:  $C_w$  shall be less than or equal to 0,1.

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

#### **18.4 Accident design condition.**

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

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

permanent loads — expected values;

functional loads — specified values;

environmental loads — specified values;

accidental loads — specified values or expected values.

**18.4.3** Loads mentioned in 13.9 and Section 15 need not be combined with each other or with wave-induced loads.

## 19 MATERIALS

**19.1** The goal of the requirements specified in this Section is to ensure that the cargo containment system, primary and secondary barriers, the thermal insulation, adjacent ship structure and other materials in the cargo containment system are constructed from materials of suitable properties for the conditions they will experience, both in normal service and in the event of failure of the primary barrier, where applicable.

### **19.2 Materials forming ship structure.**

**19.2.1** To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is below  $-10\text{ }^{\circ}\text{C}$ . The following assumptions shall be made in this calculation:

- .1** the primary barrier of all tanks shall be assumed to be at the cargo temperature;
- .2** in addition to 19.2.1.1, where a complete or partial secondary barrier is required, it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only;
- .3** for worldwide service, ambient temperatures shall be taken as  $5\text{ }^{\circ}\text{C}$  for air and  $0\text{ }^{\circ}\text{C}$  for seawater. Higher values may be accepted for ships operating in restricted areas and, conversely, lower values may be accepted for ships trading to areas where lower temperatures are expected during the winter months. During temperature calculation and selection of a steel grade for hull structures adjacent to the cargo containment system but not coming into direct contact with the ambient air the ambient temperature is taken in accordance with the technical documentation submitted in the scope of the ship project review<sup>1</sup>. For ice-breakers and ice class ships, the ambient temperature shall not be taken to be above that specified in 1.2.3.3, Part II "Hull" of the Rules for the Classification;
- .4** still air and seawater conditions shall be assumed, i.e. no adjustment for forced convection;
- .5** degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations, as defined in 19.4.6 and 19.4.7, shall be assumed;
- .6** the cooling effect of the rising boil-off vapour from the leaked cargo shall be taken into account, where applicable;
- .7** credit for hull heating may be taken in accordance with 19.2.5, provided the heating arrangements are in compliance with 19.2.6;
- .8** no credit shall be given for any means of heating, except as described in 19.2.5; and
- .9** for members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

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

**19.2.2** The shell and deck plating of the ship and all stiffeners attached thereto shall be in accordance with recognized standards. If the calculated temperature of the material in the design condition is below  $-5\text{ }^{\circ}\text{C}$  due to the influence of the cargo temperature, the material shall be in accordance with Table 2.1-5, Part IX "Materials and Welding".

**19.2.3** The materials of all other hull structures for which the calculated temperature in the design condition is below  $0\text{ }^{\circ}\text{C}$ , due to the influence of cargo temperature and that do not form the secondary barrier, shall also be in accordance with Table 2.1-5, Part IX "Materials and Welding". This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

**19.2.4** The hull material forming the secondary barrier shall be in accordance with Table 2.1-2, Part IX "Materials and Welding". Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Table 2.1-2, Part IX "Materials and Welding" shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

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<sup>1</sup>Additional provisions not included in the Code.

**19.2.5** 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 2.1-5, Part IX "Materials and Welding". In the calculations required in 19.2.1, credit for such heating may be taken in accordance with the following:

- .1 for any transverse hull structure;
- .2 for longitudinal hull structure referred to in 19.2.2 and 19.2.3 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of 5 °C for air and 0 °C for seawater with no credit taken in the calculations for heating; and
- .3 as an alternative to 19.2.5.2, for longitudinal bulkhead between cargo 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 19.2.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.

**19.2.6** The means of heating referred to in 19.2.5 shall comply with the following requirements<sup>1</sup>:

- .1 the heating system shall be arranged so that, in case of a single failure of a mechanical or electrical component in any part of the system, its intact part could ensure at least 100 % design heat supply;
- .2 the heating system shall be considered as an essential auxiliary; all electrical components of at least one of the systems provided in accordance with 19.2.5.1 (for any transverse hull structure) shall be supplied from emergency source, as specified in 6.1.4, Part VII "Electrical Equipment";
- .3 where duplication of the primary source of heat, e.g. a boiler, in the system as specified above is not feasible, alternative solutions such as electric heaters capable of providing 100 % design heat supply shall be provided. The heaters shall be supplied in accordance with 6.1.5, Part VII "Electrical Equipment"; and
- .4 the design and construction of the heating system shall be included in the approval of the containment system by the Register.

**19.3 Materials of primary and secondary barriers.**

**19.3.1** Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with Tables 2.1-1 — 2.1-3, Part IX "Materials and Welding".

**19.3.2** Materials, either non-metallic or metallic but not covered by Tables 2.1-1 — 2.1-3, Part IX "Materials and Welding", used in the primary and secondary barriers may be approved by the Register, considering the design loads that they may be subjected to, their properties and their intended use.

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

- .1 compatibility with the cargoes;
- .2 ageing;
- .3 mechanical properties;
- .4 thermal expansion and contraction;
- .5 abrasion;
- .6 cohesion;
- .7 resistance to vibrations;
- .8 resistance to fire and flame spread; and
- .9 resistance to fatigue failure and crack propagation.

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

**19.3.5 Joining of the primary and secondary barriers.**

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

**19.3.5.2** Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in Appendix 3 to these Rules.

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<sup>1</sup>Updated in compliance with IACS UI GC23.

**19.3.6** 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.

**19.4 Thermal insulation and other materials used in cargo containment systems.**

**19.4.1** Load-bearing thermal insulation and other materials used in cargo containment systems shall be suitable for the design loads.

**19.4.2** Thermal insulation and other materials used in cargo containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

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

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

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

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

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

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

## 20 CONSTRUCTION PROCESSES

**20.1** The goal of this Section is to define suitable construction processes and test procedures in order to ensure, as far as reasonably practical, that the cargo containment system will perform satisfactorily in service in accordance with the assumptions made at the design stage.

### **20.2 Weld joint design.**

**20.2.1** The requirements apply to independent tanks of type A or type B, primarily constructed of plane surfaces. This includes the tank corners which are constructed using bend plating which is aligned with the tank surfaces and connected with in-plane welds<sup>1</sup>. All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds shall also be designed with full penetration.

Welded corners (i.e. corners made of weld metal) shall not be used in the main tank shell construction, i.e. corners between shell side (sloped plane surfaces parallel to hopper or top side inclusive if any) and bottom or top of the tank, and between tank and transverse bulkheads and bottom, top or shell sides (sloped plane surfaces inclusive if any) of the tank. Instead, tank corners which are constructed using bent plating aligned with the tank surfaces and connected with in-plane welds shall be used.

Tee welds of full penetration type can be accepted for other localized constructions of the shell such as suction well, sump or dome.

**20.2.2** Welding joint details for type C independent tanks including bi-lobe tanks, primarily constructed of curved surfaces fitted with a centerline bulkhead, and for the liquid-tight primary barriers of type B independent tanks primarily constructed of curved surfaces, shall be as follows<sup>2</sup>:

**.1** all longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure;

**.2** the bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a procedure approved by the Register. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds; and

**.3** cruciform full penetration welded joints in bi-lobe tanks with centerline bulkhead can be accepted for the tank structure construction at tank centerline welds with bevel preparation subject to approval by the Register, based on the results of the tests carried out at the approval of the welding procedure.

**20.2.3** Where applicable, all the construction processes and testing, except that specified in 20.4, shall be done in accordance with the applicable provisions of Part IX "Materials and Welding".

### **20.3 Design for gluing and other joining processes.**

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

### **20.4 Testing.**

**20.4.1** All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydropneumatic pressure testing in accordance with Sections 21 — 26, as applicable for the tank type.

**20.4.2** All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 20.4.1.

**20.4.3** The requirements for inspection of secondary barriers shall be agreed with the Register, taking into account the accessibility of the barrier (refer to 6.2).

<sup>1</sup>The requirements are added considering IACS UI GC20.

<sup>2</sup>The requirements are added considering IACS UI GC21.

**20.4.4** For ships fitted with novel type B independent tanks, or tanks designed according to Section 27, at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation is recommended for elements of the type C independent tank structure, depending on their configuration and on the arrangement of their support and attachments.

**20.4.5** The overall performance of the cargo containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the cargo, in accordance with the survey procedure, requirements in Section 5, Part I "Classification" and other applicable requirements of the Register. Records of the performance of the components and equipment essential to verify the design parameters, shall be maintained and be available to the surveyor to the Register.

**20.4.6** Heating arrangements, if fitted in accordance with 19.2.5 and 19.2.6, shall be tested for required heat output and heat distribution.

**20.4.7** The cargo containment system shall be inspected for cold spots during, or immediately following, the first loaded voyage. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with procedures approved by Register.



## **21 TYPE A INDEPENDENT TANKS**

### **21.1 Design basis.**

**21.1.1** Type A independent tanks are tanks primarily designed using ship-structural analysis procedures approved by the Register. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure  $P_0$  shall be less than 0,07 MPa.

**21.1.2** If the cargo temperature at atmospheric pressure is below  $-10\text{ }^{\circ}\text{C}$ , a complete secondary barrier shall be provided as required in Section 5. The secondary barrier shall be designed in accordance with Section 6.

### **21.2 Structural analysis.**

**21.2.1** A structural analysis shall be performed taking into account the internal pressure as indicated in 13.2, and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.

**21.2.2** For parts, such as supporting structures, not otherwise covered by the requirements of these Rules, stresses shall be determined by direct calculations, taking into account the loads referred to in Sections 12 — 15 as far as applicable, and the ship deflection in way of supporting structures.

**21.2.3** The tanks with supports shall be designed for the accidental loads specified in Section 15. These loads need not be combined with each other or with environmental loads.

### **21.3 Ultimate design condition.**

**21.3.1** For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of  $R_m/2,66$  or  $R_e/1,33$  for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where  $R_m$  and  $R_e$  are defined in 18.2.3. However, if detailed calculations are carried out for the primary members, the equivalent stress  $\sigma_C$ , as defined in 18.2.4, may be increased over that indicated above to a stress acceptable to the Register. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

**21.3.2** Tank boundary scantlings shall meet the requirements of the Register for deep tanks taking into account the internal pressure as indicated in 13.2 and any corrosion allowance required by 3.5.

**21.3.3** The cargo tank structure shall be reviewed against potential buckling.

### **21.4 Accident design condition.**

**21.4.1** The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 3.4.3 and Section 15, as relevant.

**21.4.2** When subjected to the accidental loads specified in Section 15, the stress shall comply with the acceptance criteria specified in 21.3, modified as appropriate, taking into account their lower probability of occurrence.

### **21.5 Testing.**

**21.5.1** All type A independent tanks shall be subjected to a hydrostatic or hydropneumatic test. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure, including dynamic components, while avoiding stress levels that could cause permanent deformation.

## 22 TYPE B INDEPENDENT TANKS

### 22.1 Design basis.

**22.1.1** Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks), the design vapour pressure  $P_0$  shall be less than 0,07 MPa.

**22.1.2** If the cargo temperature at atmospheric pressure is below  $-10\text{ }^{\circ}\text{C}$ , a partial secondary barrier with a small leak protection system shall be provided as required in Section 5. The small leak protection system shall be designed according to Section 7.

### 22.2 Structural analysis.

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

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

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

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

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

### 22.3 Ultimate design condition.

#### 22.3.1 Plastic deformation.

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

$$\sigma_m \leq f; \quad (22.3.1.1-1)$$

$$\sigma_L \leq 1,5f; \quad (22.3.1.1-2)$$

$$\sigma_b \leq 1,5F; \quad (22.3.1.1-3)$$

$$\sigma_L + \sigma_b \leq 1,5F; \quad (22.3.1.1-4)$$

$$\sigma_m + \sigma_b \leq 1,5F; \quad (22.3.1.1-5)$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3,0F; \quad (22.3.1.1-6)$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3,0F \quad (22.3.1.1-7)$$

where  $\sigma_m$  = equivalent primary general membrane stress;  
 $\sigma_L$  = equivalent primary local membrane stress;  
 $\sigma_b$  = equivalent primary bending stress;  
 $\sigma_g$  = equivalent secondary stress;  
 $f$  = the lesser of  $(R_m/A)$  or  $(R_e/B)$ ; and  
 $F$  = the lesser of  $(R_m/C)$  or  $(R_e/D)$ ,

with  $R_m$  and  $R_e$  as defined in 18.2.4. With regard to the stresses  $\sigma_m$ ,  $\sigma_L$ ,  $\sigma_b$  and  $\sigma_g$ , the definitions of stress categories in 28.3 are referred. The values  $A$  and  $B$  shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the following minimum values as specified in Table 22.3.1.1.

Table 22.3.1.1

	Nickel steel and carbon manganese steels	Austenitic steels	Aluminium alloys
$A$	3	3,5	4
$B$	2	1,6	1,5
$C$	3	3	3
$D$	1,5	1,5	1,5

The above figures may be altered, taking into account the design condition considered, and shall be agreed with the Register.

**22.3.1.2** For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not exceed:

- .1 for nickel steels and carbon-manganese steels, the lesser of  $R_m/2$  or  $R_e/1,2$ ;
- .2 for austenitic steels, the lesser of  $R_m/2,5$  or  $R_e/1,2$ ; and
- .3 for aluminium alloys, the lesser of  $R_m/2,5$  or  $R_e/1,2$ .

The above figures may be amended, taking into account the locality of the stress, stress analysis methods and design condition considered. The figures as amended shall be agreed with the Register.

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

#### **22.3.2 Buckling.**

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

#### **22.4 Fatigue design condition.**

**22.4.1** Fatigue and crack propagation assessment shall be performed in accordance with 18.3. The acceptance criteria shall comply with 18.3.7 — 18.3.9, depending on the detectability of the defect.

**22.4.2** Fatigue analysis shall consider construction tolerances.

**22.4.3** Model tests are recommended to determine stress concentration factors and fatigue life of structural elements. The requirements for tests shall be agreed with the Register.

#### **22.5 Accident design condition.**

**22.5.1** The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 3.4.3 and Section 15, as applicable.

**22.5.2** When subjected to the accidental loads specified in Section 15, the stress shall comply with the acceptance criteria specified in 22.3, modified as appropriate, taking into account their lower probability of occurrence.

#### **22.6 Testing.**

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

- .1 the test shall be performed as required in 21.5 for type A independent tanks; and
- .2 in addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90 % of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75 % of the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

## 22.7 Marking.

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

## 23 TYPE C INDEPENDENT TANKS

### 23.1 Design basis.

**23.1.1** The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in 23.1.2 is intended to ensure that the dynamic stress is sufficiently low, so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.

**23.1.2** The design vapour pressure, in MPa, shall not be less than

$$P_0 = 0,2 + AC(\rho_r)^{1,5}, \quad (23.1.2-1)$$

where

$$A = 0,00185(\sigma_m / \Delta\sigma_A)^2;$$

$$(23.1.2-2)$$

$\sigma_m$  = design primary membrane stress;

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

55 MPa for ferritic-perlitic, martensitic and austenitic steel;

25 MPa for aluminium alloy (5083-O);

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

$h$ ,  $0,75b$  or  $0,45l$ ,

with

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

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

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

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

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

**23.1.3** The Register may allocate a tank complying with the criteria of type C tank minimum design pressure as in 23.1.2, to a type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

**23.1.4** If the carriage of products not covered by the Code<sup>1</sup> and having the relative density above 1,0 is intended, it shall be verified that the double amplitude of the primary membrane stress  $\Delta\sigma_m$  created by the maximum dynamic pressure differential  $\Delta P$  does not exceed the allowable double amplitude of the dynamic membrane stress  $\Delta\sigma_A$ , as specified in 23.1.2, i.e.

$$\Delta\sigma_m \leq \Delta\sigma_A. \quad (23.1.4-1)$$

The dynamic pressure differential  $\Delta P$ , in MPa, shall be determined by the formula

$$\Delta P = \frac{\gamma}{1,02 \times 10^5} (\alpha_{\beta 1} Z_{\beta 1} - \alpha_{\beta 2} Z_{\beta 2}), \quad (23.1.4-2)$$

where

$\gamma$  — maximum liquid cargo density, in kg/m<sup>3</sup>, at the design temperature;

$\alpha_{\beta}$ ,  $Z_{\beta}$  — refer to 28.1.2 and figure 23.1.4;

$\alpha_{\beta 1}$ ,  $Z_{\beta 1}$  are the  $\alpha_{\beta}$  and  $Z_{\beta}$  values giving the maximum liquid pressure  $(P_{gd})_{\max}$ , refer to 28.1;

$\alpha_{\beta 2}$ ,  $Z_{\beta 2}$  are the  $\alpha_{\beta}$  and  $Z_{\beta}$  values giving the minimum liquid pressure  $(P_{gd})_{\min}$ , refer to 28.1.

In order to evaluate the maximum pressure differential  $\Delta P$ , pressure differentials shall be evaluated over the full range of the acceleration ellipse as shown in the sketch in Fig. 23.1.4.

<sup>1</sup>Additional provisions from IACS UI GC7.

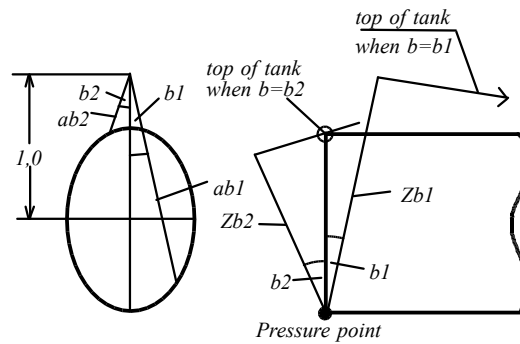


Fig. 23.1.4 Sketch for calculating a dynamic pressure differential

## 23.2 Shell thickness.

### 23.2.1 The shell thickness shall be as follows:

.1 for pressure vessels, the thickness calculated according to 23.2.4 shall be considered as a minimum thickness after forming, without any negative tolerance;

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

.3 the welded joint efficiency factor to be used in the calculation according to 23.2.4 shall be 0,95 when the inspection and the non-destructive testing referred to in 3.9, Part IX "Materials and Welding" 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, partial non-destructive examinations may be accepted, but not less than those of 3.7, Part IX "Materials and Welding", depending on such factors as the material used, the design temperature, the nil-ductility transition temperature of the material, as fabricated, and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0,85 shall be adopted. For special materials, the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

23.2.2 The design liquid pressure defined in 13.2 shall be taken into account in the internal pressure calculations.

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

$$P_e = P_1 + P_2 + P_3 + P_4, \quad (23.2.3)$$

where

- $P_1$  = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves,  $P_1$  is determined by the procedure agreed with the Register, but shall not, in general, be taken as less than 0,025 MPa;
- $P_2$  = the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere  $P_2 = 0$ ;
- $P_3$  = compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account; and
- $P_4$  = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere  $P_4 = 0$ .

23.2.4 Scantlings based on internal pressure shall be calculated as follows: the thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 13.2, including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced.

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

**.1** pressure vessel scantlings shall be determined in accordance with 23.2.1 — 23.2.4 and 23.3;

**.2** calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in Sections 12 — 15 shall be used, as applicable. Stresses in way of the supporting structures shall be determined by the procedure agreed by the Register. A fatigue analysis may be required;

**.3** secondary stresses and thermal stresses shall be considered.

**23.3 Ultimate design condition.**

**23.3.1** Plastic deformation

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

$$\sigma_m \leq f, \quad (23.3.1-1)$$

$$\sigma_L \leq 1,5f, \quad (23.3.1-2)$$

$$\sigma_b \leq 1,5f, \quad (23.3.1-3)$$

$$\sigma_L + \sigma_b \leq 1,5f, \quad (23.3.1-4)$$

$$\sigma_m + \sigma_b \leq 1,5f, \quad (23.3.1-5)$$

$$\sigma_m + \sigma_b + \sigma_g \leq 3,0f, \quad (23.3.1-6)$$

$$\sigma_L + \sigma_b + \sigma_g \leq 3,0f \quad (23.3.1-7)$$

where  $\sigma_m$  = equivalent primary general membrane stress;  
 $\sigma_L$  = equivalent primary local membrane stress;  
 $\sigma_b$  = equivalent primary bending stress;  
 $\sigma_g$  = equivalent secondary stress; and  
 $f$  = the lesser of  $(R_m/A)$  or  $(R_e/B)$ ,

with  $R_m$  and  $R_e$  as defined in 18.2.4. With regard to the stresses  $\sigma_m$ ,  $\sigma_L$ ,  $\sigma_b$  и  $\sigma_g$ , the definition of stress categories in 28.3 are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least as mentioned in Table 23.3.1.

Table 23.3.1

	Nickel steel and carbon manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	1,5	1,5	1,5

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

### 23.3.3 Permissible stresses in stiffening rings<sup>1</sup>.

For horizontal cylindrical tanks made of C-Mn steel supported in saddles, the equivalent stress in the stiffening rings shall not exceed the following values if calculated using finite element method:

$$\sigma_e \leq \sigma_{all} \quad (23.3.3-1)$$

where  $\sigma_{all} = \min(0,57R_m; 0,85R_e),$  (23.3.3-2)

$$\sigma_e = \sqrt{(\sigma_n + \sigma_b)^2 + 3\tau^2}, \quad (23.3.3-3)$$

$\sigma_e$  = von Mises equivalent stress, in MPa;

$\sigma_n$  = normal stress, in MPa, in the circumferential direction of the stiffening ring;

$\sigma_b$  = bending stress, in MPa, in the circumferential direction of the stiffening ring; and

$\tau$  = shear stress, in MPa, in the stiffening ring; and

with  $R_m$  and  $R_e$  as defined in 18.2.4.

Equivalent stress values  $\sigma_e$  shall be calculated over the full extent of the stiffening ring by a procedure with a sufficient number of load cases agreed with the Register.

### 23.3.4 Assumptions made for the stiffening rings.

The stiffening ring shall be considered as a circumferential beam formed by web, face plate, doubler plate, if any, and associated shell plating.

The effective width of the associated plating shall be taken as follows.

#### .1 For cylindrical shells:

an effective width, in mm, not greater than  $0,78\sqrt{rt}$  on each side of the web,

where  $r$  = mean radius of the cylindrical shell, in mm, and  $t$  = shell thickness, in mm.

A doubler plate, if any, may be included within that distance;

#### .2 For longitudinal bulkheads (in the case of lobe tanks):

the effective width shall be determined according to established standards. A value of  $20t_b$  on each side may be taken as a guidance value, where  $t_b$  = bulkhead thickness, in mm.

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

**23.3.5** For calculation of reaction forces at the supports, the following factors shall be taken into account:

elasticity of support material (intermediate layer of wood or similar material);

change in contact surface between tank and support, and of the relevant reactions, due to thermal shrinkage of tank, elastic deformations of tank and support material.

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

**23.3.6** The buckling strength of the stiffening rings shall be examined.

### 23.4 Fatigue design condition.

**23.4.1** For large type C independent tanks, where the cargo at atmospheric pressure is below  $-55^\circ\text{C}$ , the Register may require additional verification to check their compliance with 23.1.1 regarding static and dynamic stress.

### 23.5 Accident design condition.

**23.5.1** The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in 3.4.3 and Section 15, as applicable.

**23.5.2** When subjected to the accidental loads specified in Section 15, the stress shall comply with the acceptance criteria specified in 23.3.1, modified as appropriate taking into account their lower probability of occurrence.

<sup>1</sup>Additional provisions not included in the Code.

### **23.6 Testing.**

**23.6.1** Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than  $1,5P_0$ . In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90 % of the yield stress of the material. Where calculations indicate that this stress will exceed 0,75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

**23.6.2** The temperature of the water used for the test shall be at least 30 °C above the nil-ductility transition temperature of the material, as fabricated.

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

**23.6.4** Where necessary for cargo pressure vessels, a hydropneumatic test may be carried out under the conditions prescribed in 23.6.1 — 23.6.3.

**23.6.5** The conditions for the testing of tanks in which higher allowable stresses are used, may be amended depending on service temperature. The conditions as amended are to be approved by the Register. However, the requirements of 23.6.1 shall be fully complied with.

**23.6.6** After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test which may be performed in combination with the pressure testing referred to in 23.6.1.

**23.6.7** Pneumatic testing of pressure vessels other than cargo tanks shall be agreed by the Register. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

### **23.7 Marking.**

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

## **24 MEMBRANE TANKS**

### **24.1 Design basis.**

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

**24.1.2** A systematic approach based on analysis and testing shall be used to demonstrate that the system will provide its intended function in consideration of the events identified in service as specified in 24.2.1.

**24.1.3** If the cargo temperature at atmospheric pressure is below – 10 °C, a complete secondary barrier shall be provided as required in Section 5. The secondary barrier shall be designed according to Section 6.

**24.1.4** The design vapour pressure  $P_0$  shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation,  $P_0$  may be increased to a higher value, but less than 0,07 MPa.

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

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

**24.1.7** The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with 6.2.1, Part VI "Systems and piping", shall be sufficient to allow for effective means of gas detection.

### **24.2 Design considerations.**

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

- .1 ultimate design events:
  - tensile failure of membranes;
  - compressive collapse of thermal insulation;



- thermal ageing;
- loss of attachment between thermal insulation and hull structure;
- loss of attachment of membranes to thermal insulation system;
- structural integrity of internal structures and their supporting structures; and
- failure of the supporting hull structure;

**.2 fatigue design events:**

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

**.3 accident design events:**

- accidental mechanical damage (such as dropped objects inside the tank while in service);
- accidental overpressurization of thermal insulation spaces;
- accidental vacuum in the tank; and
- water ingress through the inner hull structure.

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

**24.2.2** The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with 24.1.2.

**24.3 Loads and load combinations.**

**24.3.1** Particular consideration shall be given to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, hull vibration effects, or any combination of these events.

**24.3.2** Methodology to determine dynamic design loads on the walls of a membrane cargo tank at its partial filling due to the sloshing effects<sup>1</sup> shall comply with the following minimum functional requirements:

**.1** methodology shall contain the data on source specifications describing the operation during the whole ship's service life, including

- the ship's main particulars;

- geometry of cargo tanks at the primary barrier level, arrangement of cargo containments over the full breadth and length;

- density and kinematic viscosity values;

- selected design levels for tank filling;

- the ship speed and distribution law of heading;

- characteristics of ship's loading conditions (the centre of gravity and centre of buoyancy position, metacentric height);

- statistics on irregular sea parameters (the provisions of IACS Recommendation No. 34 shall be met);

- special service conditions, if available (ice class);

**.2** in general, the loads shall be determined for all the cargo tanks where the partial filling is provided. In case of the available tanks identical in terms of geometrical features, it is allowed to determine the loads for those tanks where the maximum sloshing loads are expected. In addition, the methodology shall contain substantiation for the tanks selected for calculation regarding

- geometrical features and shapes of the tanks;

- arrangement of tanks over the full breadth and length of the ship relative to the centre of gravity;

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<sup>1</sup>Additional provisions not included in the Code.

.3 methodology shall contain the ship's rolling calculations. As a result of the calculation, the characteristics of oscillating movements shall be obtained for all types of rolling at irregular seas applicable to all selected operating conditions (amplitude versus frequency response characteristics or implementation on a time scale). During the rolling calculation, the methods may be applied based on the three-dimensional potential theory and other pitching and rolling calculation methods agreed with the Register;

.4 methodology shall contain the results of model sloshing tests in design cargo tanks. The model test program shall comply with the following minimum requirements:

all the main assumptions shall be specified when used during model tests;

description of the used test bench and equipment used for measuring and processing the measurement results shall be given;

substantiation for the value of scaling load factor shall be given;

the ship's oscillating movement at irregular seas shall be modelled (ship's motion characteristics can be scaled in the model test based on the Froude similarity criterion);

duration of each model test and scope of parameters characterizing each test shall be substantiated;

.5 methodology shall include description of statistical analysis of model test results. The statistical method description shall be given when used for short-term as well as long-term distribution of sloshing loads required to determine the maximum design loads on the walls of a cargo tank;

.6 when determining the maximum design loads, the results of model tests performed for sister ships with similar main dimensions and geometrical features of cargo tanks may be used. Feasible use of the results of earlier tests shall be justified considering the review of the compliance degree of, at least, the following characteristics:

the selected initial technical data;

the selected design cargo tanks;

the rolling and pitching calculation results; and

the main assumptions used during model tests.

#### **24.4 Structural analyses.**

**24.4.1** Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in Section 9, shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

**24.4.2** Structural analyses of the hull shall take into account the internal pressure as indicated in 13.2. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

**24.4.3** The analyses referred to in 24.4.1 and 24.4.2 shall be based on the particular motions, accelerations and response of ships and cargo containment systems.

#### **24.5 Ultimate design condition.**

**24.5.1** The structural resistance of every critical component, subsystem or assembly shall be established, in accordance with 24.1.2, for in-service conditions.

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

**24.5.3** The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 13.2 and the specified appropriate requirements for sloshing load as defined in 14.3.

**24.6 Fatigue design condition.**

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

**24.6.2** The fatigue calculations shall be carried out in accordance with 18.3, with relevant requirements depending on:

- .1 the significance of the structural components with respect to structural integrity; and
- .2 availability for inspection.

**24.6.3** For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes,  $C_w$  shall be less than or equal to 0,5.

**24.6.4** Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 18.3.8.

**24.6.5** Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 18.3.9.

**24.7 Accident design condition.**

**24.7.1** The containment system and the supporting hull structure shall be designed for the accidental loads specified in Section 15. These loads need not be combined with each other or with environmental loads.

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

**24.8 Design development testing.**

**24.8.1** The design development testing required in 24.1.2 shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype-scaled model of the complete cargo containment system. Testing conditions considered in the analytical and physical models shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in 6.2 may be based on the results of testing carried out on the prototype-scaled model.

**24.8.2** The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

**24.9 Testing.**

**24.9.1** In ships fitted with membrane cargo containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.

**24.9.2** All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.

**24.9.3** Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

## 25 INTEGRAL TANKS

### 25.1 Design basis.

**25.1.1** Integral tanks that form a structural part of the hull and are affected by the loads that stress the adjacent hull structure shall comply with the following:

**.1** the design vapour pressure  $P_0$  as defined in 1.2 shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly,  $P_0$  may be increased to a higher value, but less than 0,07 MPa;

**.2** integral tanks may be used for products, provided the boiling point of the cargo is not below  $-10\text{ }^{\circ}\text{C}$ . A lower temperature may be accepted, but in such cases a complete secondary barrier shall be provided; and

**.3** products required by Appendix 1 to these Rules to be carried in type **1G** ships shall not be carried in integral tanks.

### 25.2 Structural analysis.

**25.2.1** The structural analysis of integral tanks shall be in accordance with the procedure approved by the Register.

### 25.3 Ultimate design condition.

**25.3.1** The tank boundary scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 13.2.

**25.3.2** For integral tanks, allowable stresses shall normally be those given for hull structure in the RS Rules requirements.

### 25.4 Accident design condition.

**25.4.1** The tanks and the tank supports shall be designed for the accidental loads specified in 3.4.3 and Section 15, as relevant.

**25.4.2** When subjected to the accidental loads specified in Section 15, the stress shall comply with the acceptance criteria specified in 25.3, modified as appropriate, taking into account their lower probability of occurrence.

### 25.5 Testing.

**25.5.1** All integral tanks shall be hydrostatically or hydropneumatically tested. The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

## 26 SEMI-MEMBRANE TANKS

### 26.1 Design basis.

**26.1.1** Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.

**26.1.2** The design vapour pressure  $P_0$  shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation,  $P_0$  may be increased to a higher value, but less than 0,07 MPa.

**26.1.3** For semi-membrane tanks the relevant requirements of this Part of the Rules for independent tanks or for membrane tanks shall be applied as appropriate.

**26.1.4** In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, the use of a partial secondary barrier may be accepted.

## 27 LIMIT STATE DESIGN FOR NOVEL CONCEPTS OF CARGO CONTAINMENT SYSTEMS

**27.1** Cargo containment systems that are of a novel configuration that cannot be designed using Sections 21 — 26 shall be designed using this section and Sections 3 — 15, and also Sections 16 — 20, as applicable. Cargo containment system design according to this Section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using Sections 21— 26.

### 27.2 Limit state categories.

**27.2.1** 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 3.4. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

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

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

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

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

**27.3** The procedure and relevant design parameters of the limit state design shall comply with the Standards for the Use of Limit State Methodologies in the Design of Cargo Containment Systems of Novel Configuration (LSD Standard), as set out in Appendix 4 to these Rules.

## 28 ADDITIONAL PROVISIONS FOR PART IV

### 28.1 Guidance to detailed calculation of internal pressure for static design purpose.

**28.1.1** This Section provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure referred to in 13.2.4, where:

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

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

**.3**  $P_{eq}$ , in MPa, should be the greater of  $P_{eq1}$ , in MPa, and  $P_{eq2}$ , in MPa, calculated as follows:

$$P_{eq1} = P_0 + (P_{gd})_{\max}; \quad (28.1.1.3-1)$$

$$P_{eq2} = P_0 + (P_{gd \text{ site}})_{\max}. \quad (28.1.1.3-2)$$

**28.1.2** The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in 14.1. The value of internal liquid pressure  $P_{gd}$ , in MPa, resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

$$P_{gd} = \alpha_{\beta} Z_{\beta} \frac{\rho}{1,02 \times 10^5}, \quad (28.1.2-1)$$

where  $\alpha_{\beta}$  = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction  $\beta$  (refer to Fig. 28.1.2-1).

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

$Z_{\beta}$  = largest liquid height, in m, above the point where the pressure is to be determined measured from the tank shell in the  $\beta$  direction (refer to Fig. 28.1.2-2).

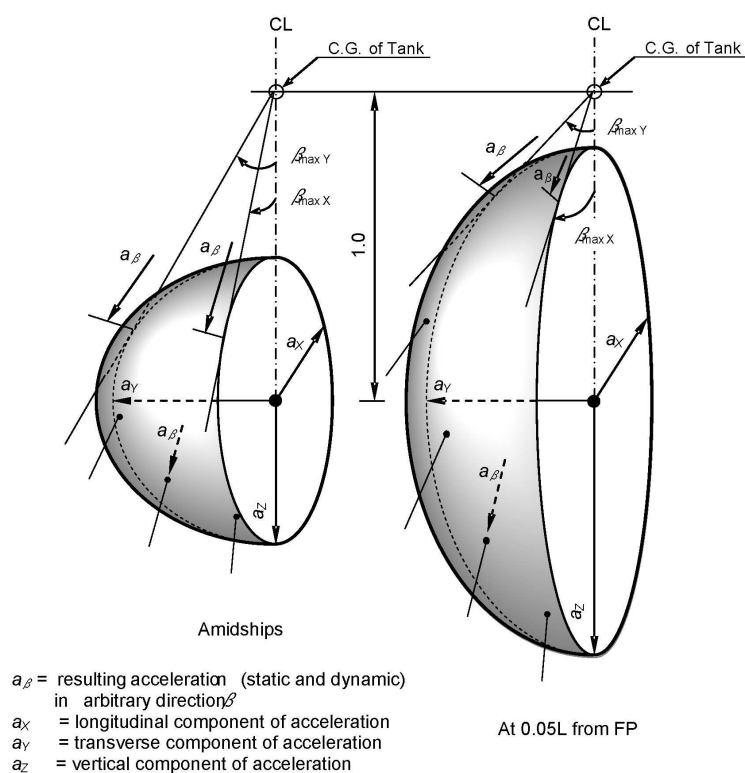


Fig. 28.1.2-1 Acceleration ellipsoid

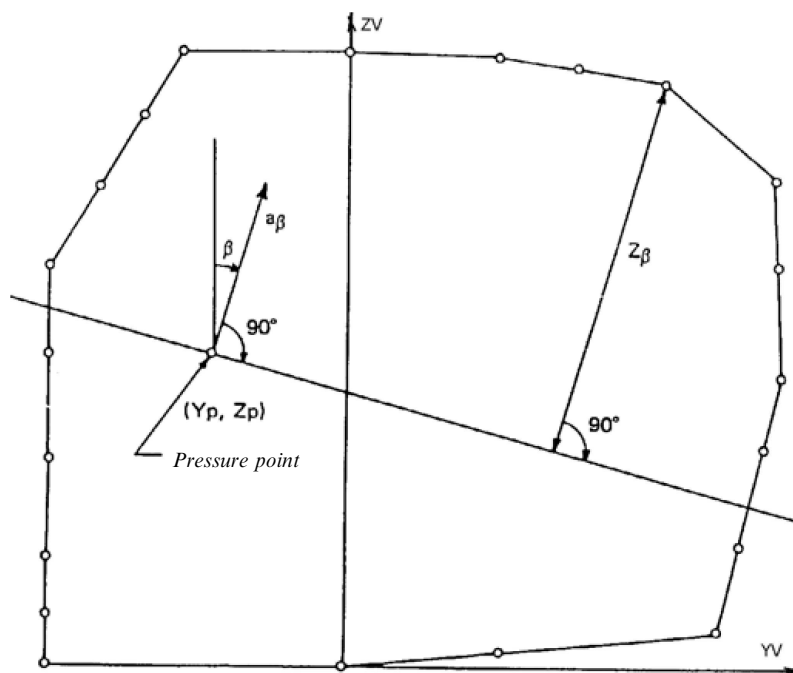


Fig. 28.1.2-2 Determination of internal pressure heads

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

$$V_d = V_t \left( \frac{100 - FL}{FL} \right), \quad (28.1.2-2)$$

with:  $V_t$  — tank volume without any domes; and  
 $FL$  — filling limit according to 3.20, Part VI "Systems and Piping";  
 $\rho$  — maximum cargo density, in  $\text{kg/m}^3$ , at the design temperature.

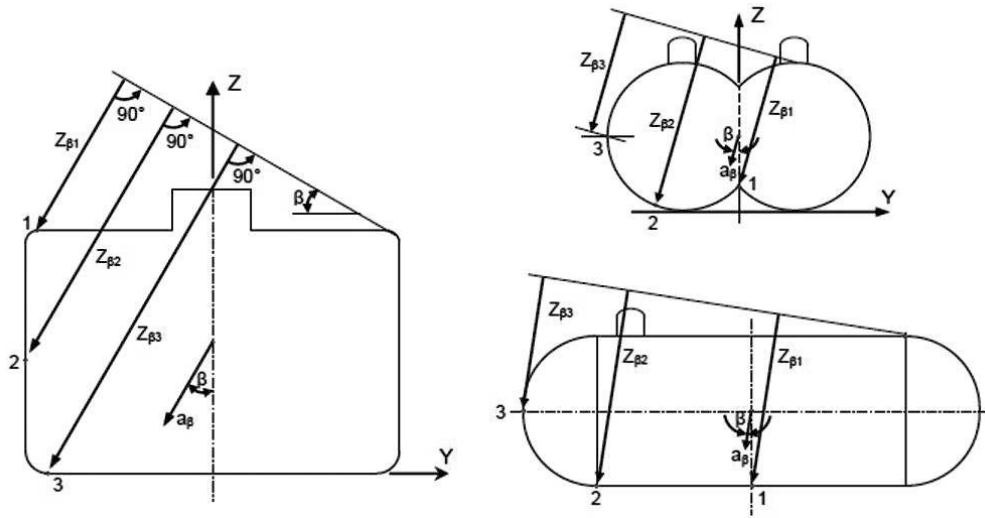


Fig. 28.1.2-3 Determination of liquid height  $Z_\beta$  for points 1, 2 and 3

The direction that gives the maximum value  $(P_{gd})_{\max}$  or  $(P_{gd \text{ site}})_{\max}$  should be considered. The above formula applies only to full tanks.

**28.1.3** Equivalent calculation procedures may be applied.

## 28.2 Guidance formulae for acceleration components.

**28.2.1** The following formulae are given as guidance for the components of acceleration due to ship's motions corresponding to a probability level of  $10^{-8}$  in the North Atlantic and apply to ships with a length exceeding 50 m and at or near their service speed:

vertical acceleration, as defined in 14.1:

$$a_z = \pm a_0 \sqrt{1 + (5.3 - \frac{45}{L_0})^2 (\frac{x}{L_0} + 0.05)^2 (\frac{0.6}{C_b})^2 + (\frac{0.6yK^{1.5}}{B})^2}, \quad (28.2.1-1)$$

transverse acceleration, as defined in 14.1:

$$a_y = \pm a_0 \sqrt{0.6 + 2.5 (\frac{x}{L_0} + 0.05)^2 + K(1 + 0.6K\frac{z}{B})^2}, \quad (28.2.1-2)$$

longitudinal acceleration, as defined in 14.1:

$$a_x = \pm a_0 \sqrt{0.06 + A^2 - 0.25A} \quad (28.2.1-3)$$

where

$$a_0 = 0.2 \frac{V}{\sqrt{L_0}} + \frac{34 - \frac{600}{L_0}}{L_0}; \quad (28.2.1-4)$$

$L_0$  = length of the ship, in m (see Part II "Hull" of the Rules for the Classification);

$C_B$  = block coefficient;

$B$  = greatest moulded breadth of the ship, in m;

$x$  = longitudinal distance, in m, from amidships to the centre of gravity of the tank with contents;  $x$  is positive forward of amidships, negative aft of amidships;

$y$  = transverse distance, in m, from centreline to the centre of gravity of the tank with contents;

$z$  = vertical distance, in m, from the ship's actual waterline to the centre of gravity of tank with contents;  $z$  is positive above and negative below the waterline;

$K=1$  in general. For particular loading conditions and hull forms, determination of  $K$  according to the following formula may be necessary:

$$K = 13GM/B, \quad (28.2.1-5)$$

where  $K \geq 1$  and  $GM$  = metacentric height (m);

$$A = (0,7 - \frac{L_0}{1200} + \frac{5z}{L_0})(\frac{0,6}{C_b}); \quad (28.2.1-6)$$

$V$  = service speed (knots);

$a_x, a_y, a_z$  = maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions. They are considered as acting separately for calculation purposes, and  $a_z$  does not include the component due to the static weight,  $a_y$  includes the component due to the static weight in the transverse direction due to rolling and  $a_x$  includes the component due to the static weight in the longitudinal direction due to pitching. The accelerations derived from the above formulae are applicable only to ships at or near their service speed, not while at anchor or otherwise near stationary in exposed locations.

### 28.3 Stress categories.

**28.3.1** For the purpose of stress evaluation, stress categories are defined in this section as follows.

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

**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.

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

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

**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.

**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.

**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:

$$S_1 \leq 0,5\sqrt{Rt}; \quad (28.3.1-1)$$

$$S_1 \geq 2,5\sqrt{Rt}, \quad (28.3.1-2)$$

where

$S_1$  = distance in the meridional direction over which the equivalent stress exceeds  $1,1f$ ;

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

$R$  = mean radius of the vessel;

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

$f$  = allowable primary general membrane stress.

**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.



## **PART V. FIRE PROTECTION**

### **1 APPLICATION**

**1.1** The requirements of the present Part apply to ship's structural fire protection, fire extinguishing systems as well as to fire fighting equipment and outfit of LG carriers. The LG carriers are also covered by all the applicable requirements of Part VI "Fire Protection" of the Rules for the Classification.

**1.2** The fire protection requirements relating to the structural members of the ship hull, machinery and electrical equipment, system and piping are set out in the relevant parts of the LG Rules.

### **2 STRUCTURAL FIRE PROTECTION**

**2.1** The applicable requirements of 2.4, Part VI "Fire Protection" of the Rules for the Classification, except 2.4.5 and 2.4.12, shall be complied with.

**2.1.1** Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the distance of at least 4 % of the length of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area (this distance, however, need not exceed 5 m) shall be of fixed (non-opening) type. Such windows and sidescuttles, except wheelhouse windows, shall be constructed to "A-60" class.

Wheelhouse windows may be non-fixed if they are designed in a manner that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.

Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type.

**2.2** All sources of ignition are to be excluded from spaces where flammable vapour may be present.

If electrical equipment is fitted in such spaces, it is to be documented that the equipment is safe for use in dangerous environment, to which it may be exposed.

**2.3** Hold spaces shall be located forward of machinery spaces of category A. They shall be separated from adjacent machinery spaces of category A, accommodation and service spaces, control stations, chain lockers, storerooms, drinking water and domestic water tanks by cofferdams or fuel tanks.

A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

In ships with cargo tanks without secondary barrier, gastight "A-60" class bulkheads may be used instead of cofferdams and fuel tanks.

Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on 1.7, Part VI "Fire Protection" of the Rules for the Classification, after further consideration of involved risks, including that of cargo release and the means of mitigation.

Turret compartments segregation from machinery spaces of category A, accommodation and service spaces, control stations, chain lockers, storerooms, drinking water and domestic water tanks or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis in accordance with 1.1.11 of the Code and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.

**2.4** Passages for safe escape from areas of the regasification unit, suction drum and export manifold shall be arranged. Shielding from fire and heat radiation shall be provided for, as necessary. Two escape ways from normally manned areas shall be arranged, one way shall be accessible after any accidental event.

**2.5** A suitable number of fire detectors including flame detectors, shall be fitted to cover the regasification units and export manifold.

### **3 FIRE FIGHTING EQUIPMENT AND SYSTEMS**

#### **3.1 General requirements.**

**3.1.1** Enclosed spaces meeting the criteria of cargo machinery spaces and the cargo motor room within the cargo area of any ship, shall be provided with a fixed fire-extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires.

**3.1.2** Enclosed spaces meeting the criteria of cargo machinery spaces and turret compartments within the cargo area of ships that are dedicated to the carriage of a restricted number of cargoes, shall be protected by an appropriate fire-extinguishing system for the cargo carried.

**3.1.3** Turret compartments of any ship shall be protected by internal water spray, with an application rate of not less than 10 l/m<sup>2</sup>/min of the largest projected horizontal surface. If the pressure of the gas flow through the turret exceeds 4 MPa, the application rate shall be increased to 20 l/m<sup>2</sup>/min.

The system shall be designed to protect all internal surfaces.

**3.1.4** The automatic sound alarms to warn of the fire extinguishing in the above spaces are to be safe for use in a flammable cargo vapour-air mixture.

#### **3.2 Water fire main system.**

**3.2.1** Water fire main system is to meet the requirements of 3.2, Part VI "Fire Protection" of the Rules for the Classification, having regard to the following:

**.1** when a fire pump is used to supply the water-spray system (refer to 3.3.5), limitations in 3.2.1.5.2 and 3.2.5.1, Part VI "Fire Protection" of the Rules for the Classification are not applied. The capacity of fire pumps shall be such that the areas mentioned in 3.3.1 can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 0,5 MPa;

**.2** the arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers that are above the deck;

**.3** the necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of 3.2.6.2 and 5.1.5, Part VI "Fire Protection" of the Rules for the Classification with hose lengths as specified in 5.1.4, Part VI "Fire Protection" of the Rules for the Classification;

**.4** the requirements of Table 3.2.1.1, Part VI "Fire Protection" of the Rules for the Classification shall be met at a pressure of at least 0,5 MPa gauge;

**.5** stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that requirements in 3.2.1.2 and 3.2.1.3 can be complied with using not more than two lengths of hoses from the nearest fire hydrant;

**.6** the water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned fore and aft of the cargo area, one of which shall be independently driven;

**.7** after installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

**3.2.2** When the ship is fitted with a total flooding high expansion foam system protecting the category A engine-room and the emergency fire pump is intended to supply sea water to this system, then, the emergency fire pump shall also be sized up to cover the foam system for dealing with an engine-room fire when the main fire pumps are disabled.

**3.2.3** On the basis of the principle of dealing with one single incident at a time, the emergency pump does not need to be sized to cover fire hydrants, foam system in accordance with the requirements of 3.2.2 and water-spray system in accordance with the requirements of 3.3.6 at the same time.

At that, it shall be sized to simultaneously cover the foam system and two hydrants in accordance with the requirements of 3.2.2 or the water-spray system and two hydrants in accordance with the requirements of 3.3.6, whichever is greater.

### **3.3 Water-spray system.**

**3.3.1** On ships carrying flammable and/or toxic products, a water-spray system, for cooling, fire prevention and crew protection shall be installed to cover:

**.1** exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks;

**.2** exposed on-deck storage vessels for flammable or toxic products;

**.3** gas process units positioned on deck;

**.4** cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided;

**.5** all exposed emergency shut-down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers;

**.6** exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire-risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire-risk items or equipment do not require water-spray protection;

**.7** exposed lifeboats, liferafts and muster stations facing the cargo area, regardless of distance to cargo area, except for the exposed muster stations and exposed launching routes from the life rafts storage location to the ship side where rafts are located and ready for launching at both sides (remote liferafts located in areas covered by water-spray protection as required in 3.3.1.6, are considered as adequately protected); and

**.8** any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room.

Water-spray system of ships intended for periodical operation at a fixed location in regasification and offloading mode or in the receiving, processing, liquefying and storage modes shall be designed in compliance with the requirements of 1.1.10 of the Code.

**3.3.2** The system shall be capable of covering all areas mentioned in 3.3.1 with a uniformly distributed water application rate of at least 10 l/m<sup>2</sup>/min for the largest projected horizontal surfaces and 4 l/m<sup>2</sup>/min for vertical surfaces.

On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas.

For structures having no clearly defined horizontal or vertical surface, the capacity of the water-spray system shall not be less than the projected horizontal surface multiplied by 10 l/m<sup>2</sup>/min.

For the purposes of firefighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area mentioned in 3.3.1.6 and 3.3.1.7.

**3.3.3** Stop valves shall be fitted in the main supply line(s) in the water-spray system, at intervals not exceeding 40 m, 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 outside the cargo area.

**3.3.4** A section protecting any area included in 3.3.1.1 and 3.3.1.2 shall cover at least the entire athwartship tank grouping in that area.

Any gas process unit(s) included in 3.3.1.3 may be served by an independent section.

**3.3.5** In addition to surfaces specified in 3.3.1.4 — 3.3.1.8, the capacity of the water-spray pumps shall be capable of simultaneous protection of the greater of the following:

**.1** any two complete athwartship tank groupings including any gas process units within these areas, where one group is defined as tanks located in transverse direction from ship side to ship side; where there is only one cargo tank occupying a hold space from ship side to ship side, it is considered as a "grouping"; the area of any two complete tank groupings shall be equal to the combined area of the two largest tank groupings including any gas process units within these areas;

.2 for ships intended for operation as stipulated in 1.1.10 of the Code — of any added fire hazard and the adjacent athwartship tank grouping.

Alternatively, the main fire pumps may be used for this service, provided that their total capacity is increased by the amount needed for the water-spray system.

In either case, a connection, through a stop valve, shall be made between the fire main and water-spray system main supply line outside the cargo area.

**3.3.6** The boundaries of superstructures and deckhouses normally manned, and lifeboats, liferafts and muster areas facing the cargo area, shall also be capable of being served by one of the fire pumps specified in 3.2.1.1, Part VI "Fire Protection" of the Rules for the Classification and installed outside the spaces where spray pumps are located or emergency fire pump, in case fire in one compartment (meaning a compartment provided with A-class boundaries in which fire pump(s) is(are) located or the source of power of the fire pump(s), serving the water-spray system in accordance with 3.3.2) could disable both fire pumps. Emergency fire pump capacity shall be capable of maintaining two jets of water in accordance with 3.2.4.7, Part VI "Fire Protection" of the Rules for the Classification and spray application rates stated in 3.3.2, but limiting coverage to boundaries of normally manned superstructures and deckhouses, survival crafts and their muster areas.

**3.3.7** Water pumps normally used for other services may be arranged to supply the water-spray system main supply line.

**3.3.8** All pipes, valves, nozzles and other fittings in the water-spray system shall be resistant to corrosion by seawater. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925 °C.

**3.3.9** The water-spray system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition, means shall be provided to back-flush the system with fresh water.

**3.3.10** Remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system shall be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the protected areas.

**3.3.11** After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

**3.3.12** For ships fitted with the regasification plant, the water spray system shall meet the additional requirements:

.1 the fire water main shall be designed and equipped with isolation valves such that no single accidental event disrupt firewater supply to the spray water system;

.2 a water-spray system with an application rate according to 3.3.2 shall be arranged to protect:

the regasification units;

metering station;

suction drum;

export manifold;

internal surfaces of the turret compartment;

storage tanks for any flammable fluids or gases, if fitted on the weather deck;

.3 the arrangements and capacities of the water spray system shall be such that with one spray pump system out of operation the remaining pump system shall have capacity to supply the water spray system;

.4 if the fire water pumps and spray pumps are combined, the capacity shall be sufficient to supply water spray to the largest fire section as well as two fire hoses;

.5 release of the water spray systems shall be possible both locally and remotely at the control station where the operating status of the systems is monitored;

.6 the regasification plants shall be covered by a dry chemical powder fire-extinguishing system complying with the requirements in 3.4.

#### **3.4 Dry chemical powder fire extinguishing system.**

**3.4.1** Ships in which the carriage of flammable products is intended shall be fitted with fixed dry chemical powder fire-extinguishing systems, approved by MSC.1/Circ.1315 "Guidelines for the approval of fixed dry chemical powder fire-extinguishing systems for the protection of ships carrying liquefied

gases in bulk" for the purpose of firefighting on the deck in the cargo area, including any cargo liquid and vapour discharge and loading connections on deck and bow or stern cargo handling areas.

**3.4.2** The system shall be capable of delivering powder from at least two hand hose lines, or a combination of monitor/hand hose lines, to any part of the exposed cargo liquid and vapour piping, load/unload connection and exposed gas process units.

**3.4.3** The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by 3.4.2 shall be capable of being reached from not less than two independent units with associated controls, pressurizing medium fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1000 m<sup>3</sup>, only one such unit need be fitted.

**3.4.4** A monitor shall be arranged to protect any load/unload connection area and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed, if it can deliver the necessary powder to all required areas of coverage from a single position.

**3.4.5** One hose line shall be provided at both port- and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.

**3.4.6** The capacity of a monitor shall be not less than 10 kg/s.

Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3,5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33 m.

Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.

**3.4.7** Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidized state during sustained or intermittent use, and which can be purged of powder when the system is shut down.

**3.4.8** Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose.

**3.4.9** Ships fitted with bow/stern load/unload connections shall be provided with independent dry powder unit protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow/stern load/unload complying with the requirements of 3.4.1 — 3.4.8.

**3.4.10** The dry chemical powder fire-extinguishing system of ships intended for periodical operation at a fixed location in regasification and offloading mode or in the receiving, processing, liquefying and storage modes shall be designed in compliance with the requirements of 1.1.10 of the Code.

**3.4.11** After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. Testing arrangements shall involve the discharge from all monitors and hand hose lines on board, but it is not required that there is a full discharge of the installed quantity of dry powder.

After the completion of this testing, the system, including all monitors and hand hose lines, shall be blown through with dry air for the purpose of the system subsequently being clear from any residues of dry chemical powder.

#### 4 PERSONNEL PROTECTION

**4.1** Every ship carrying flammable products shall carry firefighter's outfits complying with the requirements of 5.1.15, Part VI "Fire Protection" of the Rules for the Classification in the numbers specified in Table 4.1.

Table 4.1

Total cargo capacity	Number of outfits
5000 m <sup>3</sup> and below	4
Above 5000 m <sup>3</sup>	5

**4.2** Any breathing apparatus required as part of a firefighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1200 l of free air.

**4.3** Suitable protective equipment, including eye protection to a recognized national or international standard, shall be provided to protect crew members involved in normal loading and discharging operations, with due regard for the characteristics of the products being carried.

**4.4** The personal protective equipment shall be kept in clearly marked lockers located in readily accessible places.

**4.5** Sufficient, but not less than three complete sets of safety equipment in addition to the fireman's outfit required by 4.1 each permitting personnel to enter and work in gas-filled spaces, shall be provided.

**4.6** One complete set of safety equipment required by 4.5 shall consist of:

.1 one self-contained positive pressure air-breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1,200 l of free air. Each set shall be compatible with that required by 4.1;

.2 protective clothing, boots and gloves to a recognized standard;

.3 steel-cored rescue line with belt; and

.4 explosion-proof lamp.

**4.7** An adequate supply of compressed air for the air-breathing apparatus required in 4.2 and 4.6 shall be provided and shall consist of:

.1 at least one fully charged spare air bottle for each breathing apparatus;

.2 an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high-pressure air of breathable quality; and

.3 a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus.

**4.8** Safety equipment required in 4.5, 4.6 and 4.7 shall be kept in special clearly marked lockers located in readily accessible places.

**4.9** The protective clothing required in 4.6.2 shall be gastight.

#### **4.10 First-aid equipment.**

**4.10.1** A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.

**4.10.2** The ship shall have onboard medical first-aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) on rendering first-aid in accidents associated with dangerous cargoes as well as considering the characteristics of the cargoes being carried.

## **PART VI. SYSTEMS AND PIPING**

### **1 GENERAL**

**1.1** This Part supplements Part VIII "Systems and Piping" of the Rules for the Classification and sets forth the requirements for the special systems and piping of gas LG carriers.

**1.2** Pumps, piping, valves and other fittings of the systems arranged in way of cargo tanks are to have identification markings.

**1.3** Any pressure vessels shall meet the requirements in Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification. The requirements for type C independent tanks provided in Part IV "Cargo Containment" may also apply to the process pressure vessels, including surge tanks, heat exchangers and accumulators that store or treat liquid or vapour cargo. The term "pressure vessels" as used in Part IV "Cargo Containment", covers both type C independent tanks and process pressure vessels.

### **2 PIPING**

#### **2.1 Materials.**

**2.1.1** The piping and valves used at a working temperature from 0 to  $-165\text{ }^{\circ}\text{C}$  shall be made of the materials mentioned in Table 2.1-4, Part IX "Materials and Welding". The choice and testing of materials used in piping systems shall comply with the requirements of Section 2, Part IX "Materials and Welding" taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open-ended vent piping, provided that the temperature of the cargo at the pressure relief valve (PRV) setting is not lower than  $-55\text{ }^{\circ}\text{C}$ , and that no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open-ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.

**2.1.2** Materials having a melting point below  $925\text{ }^{\circ}\text{C}$  shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.

#### **2.1.3 Cargo piping insulation system.**

**2.1.3.1** Cargo piping systems shall be provided with a thermal insulation system as required to minimize heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.

Properties of the thermal insulation of cargo piping systems shall be taken into consideration when calculating the heat balance of the containment system and capacity of the pressure/temperature control system. Surfaces of cargo piping systems with which personnel is likely to contact under normal conditions shall be protected by a thermal insulation, with the exception of the following examples:

- surfaces of cargo piping systems which are protected by physical screening measures to prevent such direct contact;

- surfaces of manual valves having extended spindles that protect the operator from the cargo temperature;

- surfaces of cargo piping systems whose design temperature (to be determined from inner fluid temperature) is  $-10\text{ }^{\circ}\text{C}$ .

**2.1.3.2** Where applicable, due to location or environmental conditions, insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage.

**2.1.4** Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, adequate measures to avoid this occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.

**2.1.5** For an outer pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, the effects of both pressure and possible low temperature in the event of a high pressure line failure shall be taken into account.

**2.2 Pipe wall thickness.**

**2.2.1** The wall thickness of pipes operating under the internal pressure is to be not less than that determined by Formula (2.3.1), Part VIII "Systems and Piping" of the Rules for the Classification with due regard for the following values involved in the formula.

**2.2.1.1**  $p$  (design pressure) is the maximum pressure, to which the system may be subjected in service.

The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:

for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid, the saturated vapour pressure at a design temperature of 45 °C. Higher or lower values may be used (refer to 13.2, Part IV "Cargo Containment"); or

for systems or components that may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45 °C. Higher or lower values may be used (refer to 13.2, Part IV "Cargo Containment"), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

the MARVS of the cargo tanks and cargo processing systems; or

the pressure setting of the associated pump or compressor discharge relief valve; or

the maximum total discharge or loading head of the cargo piping system; or

the relief valve setting on a pipeline system.

In any case, the design pressure  $p$  is not to be less than 1 MPa except for open-ended lines where it is to be not less than 0,5 MPa or 10 times that of the relief valve setting.

Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this pressure.

The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively, for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

**2.2.1.2**  $c$  is the corrosion allowance; it may be increased over the required in 2.3.1, Part VIII "Systems and Piping" of the Rules for the Classification if enhanced corrosion or piping erosion is expected. This allowance is to be consistent with the expected life of the piping.

**2.2.1.3** The remaining values involved in the formula are to meet the requirements of 2.3.1, Part VIII "Systems and Piping" of the Rules for the Classification; no reduction of the safety factors is allowed.

**2.2.1.4** The minimum material ultimate strength and yield stress safety factors accepted for the cargo pipeline are to be specified in the Certificate.

**2.2.2** The minimum pipe wall thickness is to be taken in accordance with Table 2.3.8, Part VIII "Systems and Piping" of the Rules for the Classification or standards agreed with the Register.

Where necessary for mechanical strength to prevent damage of pipes resulted from excessive sag due to superimposed loads from supports, ship deflection or other causes, the wall thickness is to be increased over that required by 2.2.1. If this is impracticable or would cause excessive local stresses, these loads are to be reduced or eliminated completely by other design methods.

Such superimposed loads may be due to: supporting structures, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

**2.2.3** When the design temperature of the medium is  $-110$  °C or lower, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system is to be submitted to the Register.

For temperatures of above  $-110$  °C, a stress analysis may be required by the Register in relation to such matters as the design or stiffness of the piping system and the choice of materials.



Such analysis is to be carried out according to methods approved by the Register.

In any case, consideration is to be given to thermal stresses, even though calculations are not submitted.

**2.2.4 High-pressure gas fuel outer pipes or ducting scantlings.**

**2.2.4.1** In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1,5 ( $R_m/1,5$ ) when subjected to the design pressure specified in 2.2.1. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

**2.3 Pipe joints.**

**2.3.1** The present requirements apply to piping inside and outside the cargo tanks. On agreement with the Register, relaxations from these requirements may be accepted for piping inside cargo tanks and open-ended piping.

**2.3.2** Butt-welded joints with complete penetration may be used in all applications. For design temperatures below  $-10\text{ }^{\circ}\text{C}$ , 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 MPa and design temperatures of  $-10\text{ }^{\circ}\text{C}$  or lower, backing rings are to be removed after welding. The scope of non-destructive testing is to be not less than that required in 3.3.3, Part XIV "Welding" of the Rules for the Classification, for Class I piping.

**2.3.3** Flange connections of piping, valves and other fittings are to meet the requirements of 2.4.3, Part VIII "Systems and Piping" of the Rules for the Classification.

The type B flange connections are not to be used for the design temperatures lower than  $-10\text{ }^{\circ}\text{C}$  and in nominal sizes above 100 mm.

The strength dimensions of the flanges are to be determined in accordance with standards approved by the Register for the design pressure accepted in compliance with 2.2.1.1.

**2.3.4** Sleep-on welded joints with sleeves and related welding are only to be used for open-ended lines with external diameter of 50 mm or less and design temperature not lower than  $-55\text{ }^{\circ}\text{C}$ .

**2.3.5** On agreement with the Register, screwed couplings may only be used for accessory lines with external diameter of 25 mm or less.

**2.3.6** Where bellows and expansion joints are used in the piping, they are to be held to a minimum but their number is to be sufficient to protect the pipelines and individual assemblies of the system against excessive stresses due to thermal expansion of the cargo tanks, pipelines and ship's hull deformations.

Bellows may be only installed outside the cargo tanks. Expansion joints of other types may be installed inside the cargo tanks.

If necessary, bellows are to be protected against icing.

The design and installation of expansion bellows shall be in accordance with recognized standard, and they shall be fitted with means to prevent damage due to over-extension or compression.

**2.4 Heat treatment of pipes.**

**2.4.1** Post-weld heat treatment is to be required for all butt welds of liquefied gas pipes made with carbon, carbon-manganese and low alloy steels.

**2.4.2** The Register may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

**2.5 Insulation of piping.**

Pipelines intended for media with low temperature are to be thermally isolated from the adjacent hull structures, where necessary, in order to prevent the temperature of these structures from falling below the design temperature.

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

## **2.6 Piping arrangement.**

**2.6.1** Any piping system that may contain cargo liquid or vapour shall:

**.1** be segregated from other piping systems, except where interconnections are required for cargo-related operations such as purging, gas-freeing or inerting. The requirements of 6.1.4 shall be taken into account with regard to preventing back-flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections;

**.2** except as provided in Section 11, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo machinery space;

**.3** be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkway or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams;

**.4** be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements, emergency cargo jettisoning piping systems, turret compartment systems and except in accordance with Section 11. The emergency cargo jettisoning piping system may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them; and

**.5** be located inboard of the transverse tank location requirements of Section 2, Part II "Ship Arrangement", except for athwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning piping systems.

## **2.7 Side overboard discharges below freeboard deck.**

**2.7.1** Provision and control of valves fitted at the side overboard discharges of piping from spaces situated below the freeboard deck, or from enclosed superstructures and deckhouses on the freeboard deck are to comply with the requirements of 4.3.2, Part VIII "Systems and Piping" of the Rules for the Classification.

**2.7.2** The choice of the valves is to be based on the following.

**2.7.2.1** The overboard discharges are generally to be provided with one automatically operated non-return valve with a positive means of closing positioned above the freeboard deck.

**2.7.2.2** Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01 of the ship's length, the discharge opening may have two automatically operated non-return valves without positive means of closing provided that the inboard valve is readily accessible for inspection under service conditions.

# **3 CARGO SYSTEM**

## **3.1 System and arrangement requirements.**

**3.1.1** The cargo handling and cargo control systems shall be designed taking into account the following:

**.1** prevention of an abnormal condition escalating to a release of liquid or vapour cargo;

**.2** the safe collection and disposal of cargo fluids released;

**.3** prevention of the formation of flammable mixtures;

**.4** prevention of ignition of flammable liquids or gases and vapours released; and;

**.5** limiting the exposure of personnel to fire and other hazards.

**3.1.2** Suitable means shall be provided to relieve the pressure and remove liquid cargo from loading and discharging crossover headers; likewise, any piping between the outermost manifold valves and loading arms or cargo hoses to the cargo tanks.

**3.1.3** Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area.

**3.1.4** Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the cargo vent mast, if means are provided to detect and dispose of any liquid cargo that may flow into the vent system. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.

### **3.2 Cargo system valve requirements.**

**3.2.1** Every cargo tank and piping system shall be fitted with manually operated valves for isolation purposes as specified in this Section.

**3.2.2** In addition, remotely operated valves shall also be fitted, as appropriate, as part of the emergency shutdown (ESD) system the purpose of which is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress. The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework. The equipment to be shut down on ESD activation includes manifold valves during loading or discharge, any pump or compressor, etc., transferring cargo internally or externally (e.g. to shore or another ship/barge) and cargo tank valves, if the MARVS exceeds 0,07 MPa.

### **3.3 Cargo tank connections.**

**3.3.1** All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shutoff valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation. They may also be capable of remote operation.

**3.3.2** For cargo tanks with a MARVS exceeding 0,07 MPa gauge, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves, provided the valve complies with the requirements of 3.21.6 and provides full closure of the line.

### **3.4 Cargo manifold connections.**

**3.4.1** One remotely controlled ESD valve shall be provided at each cargo transfer connection in use to stop liquid and vapour transfer to or from the ship. Transfer connections not in use shall be isolated with suitable blank flanges.

**3.4.2** If the cargo tank MARVS exceeds 0,07 MPa, an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the ship's design.

**3.4.3** Excess flow valves may be used in lieu of ESD valves, if the diameter of the protected pipe does not exceed 50 mm. Excess flow valves shall close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves and appurtenances protected by an excess flow valve shall have a capacity greater than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding the area of a 1 mm diameter circular opening to allow equalization of pressure after a shutdown activation.

**3.4.4** Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves, provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1,5 mm diameter circular hole.

**3.4.5** All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation.

**3.4.6** All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0,05 m<sup>3</sup>, entrapped shall be provided with PRVs sized for a fire condition according to 3.19.1.

### **3.5 Cargo transfer arrangements.**

**3.5.1** Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank, and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

**3.5.2** The procedure for transfer of cargo by gas pressurization shall preclude lifting of the relief valves during such transfer. Gas pressurization may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as it is permitted in accordance with IGC Code, the new set pressure shall not exceed  $P_h$  as is defined in Section 1, Part IV "Cargo Containment".

### **3.6 Vapour return connections.**

**3.6.1** Connections for vapour return to the shore installations shall be provided.

### **3.7 Cargo tank vent piping systems.**

**3.7.1** The pressure relief system shall be connected to a vent piping system designed to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.

### **3.8 Cargo sampling connections.**

**3.8.1** Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimize the release of cargo vapours. For vessels permitted to carry toxic products, the sampling system shall be of a closed loop design to ensure that cargo liquid and vapour are not vented to atmosphere.

**3.8.2** Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.

**3.8.3** On closed loop systems, the valves on the return pipe shall also comply with 3.8.2.

**3.8.4** The connection to the sample container shall comply with recognized standards and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.

**3.8.5** Sample connections used only for vapour samples may be fitted with a single valve in accordance with 2.3, 3.2 and Section 11 and shall also be fitted with a closure plug or flange.

### **3.9 Cargo filters.**

**3.9.1** The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by extraneous objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris, etc., entering the cargo system. Means shall be provided to indicate that filters are becoming blocked, and to isolate, depressurize and clean the filters safely.

### **3.10 Piping installation requirements.**

**3.10.1** Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.

**3.10.2** Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections and at pump seals, protection for the hull beneath shall be provided.

**3.10.3** For cargo temperatures below – 110 °C, a water distribution system shall be fitted in way of the hull under the shore connections to provide a low-pressure water curtain for additional protection of the hull steel and the ship's side structure. This system is in addition to the requirements of 3.3, Part V "Fire Protection" and shall be operated when cargo transfer is in progress.

**3.10.4** Where tanks or cargo piping and piping equipment are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1 MOhm.

### **3.11 Arrangements for cargo piping outside the cargo area.**

#### **3.11.1 Emergency cargo jettisoning.**

**3.11.1.1** If fitted, an emergency cargo jettisoning piping system may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.

### **3.12 Bow and stern loading arrangements.**

**3.12.1** Subject to the requirements of this Section, cargo piping may be arranged to permit bow or stern loading and unloading.

**3.12.2** Arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

**3.12.3** Cargo piping and related piping equipment outside the cargo area shall have only welded connections. The piping outside the cargo area shall run on the weather decks and shall be at least 0,8 m inboard, except for athwartships shore connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it shall also be capable of being separated by means of a removable spool piece and blank flanges, when not in use.

**3.12.4** The piping shall be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the shore connection.

**3.13 Turret compartment transfer systems.**

**3.13.1** For the transfer of liquid or vapour cargo through an internal turret arrangement located outside the cargo area, the piping serving this purpose shall comply with the following:

.1 piping shall be located above the weather deck, except for the connection to the turret;

.2 portable arrangements shall not be permitted; and

.3 arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area;

.4 cargo piping and related piping equipment outside the cargo area shall have only welded connections; and

.5 the piping shall be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

**3.14 Pumps and compressors.**

**3.14.1** To transfer the liquefied gases, centrifugal, peripheral and steam-driven direct acting pumps of special design may be used.

The construction of the pumps is to include special sealing components to keep the suction pressure above the liquid phase saturated vapour pressure at the maximum temperature.

**3.14.2** Single-stage and double-stage compressors may be used to transfer liquefied gases cargo vapours.

**3.14.3** Where cargo transfer is by means of cargo pumps not accessible for repair with the tanks in service, at least two separate means are to be provided to transfer cargo from each tank and the design is to be such that failure of one cargo pump, or means of transfer, will not prevent the cargo transfer by another cargo pump or pumps, or other cargo transfer means.

**3.14.4** Relief valves are to be provided for pumps and compressors the delivery pressure of which may exceed the design pressure in the system.

**3.14.5** The procedure for transfer of cargo by gas pressurization is to preclude lifting of the relief valves during such transfer.

**3.14.6** The cargo pumps and compressors are to be arranged to shutdown automatically if:

emergency shutdown valves in pressure pipelines required by 3.15.1 are closed by the emergency shutdown system required by 3.15.4;

prescribed cargo level in cargo tank is reached;

pressure in the cargo tank drops to the minimum allowable value.

**3.14.7** Cargo hoses are to have Type Approval Certificates and meet the requirements of Section 6, Part VIII "Systems and Piping" of the Rules for the Classification.

**3.15 Piping and valves.**

**3.15.1** Every cargo piping system and cargo tank is to be provided with the emergency shutdown valves.

**3.15.1.1** For cargo tanks with MARVS not exceeding 0,07 MPa, all liquid and vapour connections, except safety relief valves and closed liquid level gauging devices which penetrate the cargo tank, are to have shutoff valves located as close to the tank as practicable. These valves may be remotely controlled but are to be capable of local manual operation and provide full closure.

Remotely controlled emergency shutdown valves are to be provided on the ship for shutting down liquid and vapour cargo transfer between ship and shore and are to meet the requirements of 3.15.3 and 3.15.4.

**3.15.1.2** For cargo tanks with MARVS exceeding 0,07 MPa, all liquid and vapour connections, except safety relief valves and closed liquid level gauging devices which penetrate the cargo tank, are to be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves are to be located as close to the tank as practicable.

Where the pipe size does not exceed 50 mm in diameter, excess flow valves specified in 3.15.5 may be used in lieu of the emergency shutdown valve.

A single valve may be substituted for the two separate valves provided the valve complies with the requirements of 3.15.4, is capable of local manual operation and provides full closure.

**3.15.2** Cargo tank connections for gauging or measuring devices need not be equipped with excess flow or emergency shutdown valves provided that the internal diameter of a connection does not exceed 1,5 mm.

**3.15.3** One remotely operated emergency shutdown valve is to be provided at each cargo hose connection. Connections not used in transfer operations may be blinded with blank flanges.

**3.15.4** All required emergency shutdown valves are to be controlled from at least two remote locations on the ship. One of these locations is to be the cargo control room.

The control system is to be also provided with fusible elements designed to melt at temperatures 98 to 104 °C which will cause the emergency shutdown valves to close in the event of fire. Locations for such fusible elements are to include the tank domes and loading stations.

Emergency shutdown valves are to be of the fail-closed (closed on loss of power) type and be capable of local manual closing operation.

It is recommended that the valve closing operation is performed without use of a remote power supply but by physical mechanical over-ride forcing the valve onto its seat. Along with that, a clear indication of the valve opening and closing position is to be provided. The operating instruction of the valve Manufacturer is to be kept on board the ship and provide technical information on installation, maintenance, including disassembly and assembly, periodic inspections, including external and inner examinations and testing by pressure equal to the working pressure.

Emergency shutdown valves in liquid piping are to fully close under all service conditions with 30 s of actuation.

Valves connected with the high liquid level alarm and the sensor for automatic closure thereof, in accordance with Part VIII "Instrumentation and Automation System" are to comply with the following requirements to control overpressure in the cargo main and prevent the cargo tank from becoming liquid full.

**3.15.4.1** The total valve closure time (i.e. the time from shutdown signal initiation to complete valve closure), in s, is not to exceed  $3600U/LR$  (where  $U$  is ullage volume at operating signal level, in m<sup>3</sup>;  $LR$  is the maximum loading rate agreed between ship and shore facility, in m<sup>3</sup>/h) and is to be such as to avoid surge pressures.

**3.15.4.2** The total valve closure time is to be such as to prevent pressure increase during closure of the valve above the acceptable level.

Information on the closing time of the valves and their operating characteristics is to be available on board and the valve closure time is to be verifiable and reproducible. Such valves are to close in such a manner as to cut off the flow smoothly.

**3.15.5** Excess flow valve is to close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer.

The piping including fittings, valves and appurtenances protected by an excess flow valve, are to have greater capacity than the rated closing flow of the excess flow valve.

Excess flow valves may be designed with a bypass not exceeding an area of 1,0 mm diameter circular opening to allow equalization of pressure, after an operating shutdown.

**3.15.6** All pipelines or components which may be isolated in a liquid-full condition from the cargo piping systems and tanks are to be provided with relief valves.

Relief valves discharging liquid cargo from the cargo piping system are to discharge to the cargo vent mast if means are provided to detect and dispose of any liquid cargo which may flow into the vent system.

Relief valves on cargo pumps are to discharge to the pump suction.

**3.15.7** Suitable means are to be provided to relief the pressure and remove liquid contents from cargo loading and discharging crossover headers and cargo hoses to the cargo tanks or other suitable location, prior to disconnecting the cargo hoses (see 3.15.10).

**3.15.8** On agreement with the Register, for the purpose of carrying out cargo handling operations from bow and stern, cargo piping may be laid aft or forward outside the cargo area in accordance with 3.15.9 and 3.15.10, but it is not to be used for transfer of toxic goods.

Connections for the cargo hoses are to be arranged as follows.

**3.15.8.1** Entrances, air intakes and opening leading to the accommodation, service and machinery spaces as well as control stations are not to face the shore connections of bow or stern loading and discharging arrangements. They are to be situated at the superstructure or deckhouse side at a distance equal to at least 4 % of ship length or 3 m from the deckhouse end facing the shore connection of the bow or stern loading and discharging arrangements. This distance need not, however, to exceed 5 m. Sidelights facing the side where the shore connections are fitted and situated on the superstructure or deckhouse side within the above distance are to be of dead (non-opening) type. Also, when the bow or stern loading and discharging arrangements are used, all doors, cargo ports and other openings situated on the relevant side of the superstructure or deckhouse are to be kept closed at all times.

**3.15.8.2** Deck opening and air intakes located at a distance of 10 m from the position of the shore connection of the bow or stern loading and discharging arrangements are to be kept closed over the whole period when these arrangements are used.

**3.15.8.3** Electrical equipment located within the 3 m zone from the position of the shore connection of the above arrangements is to meet the requirements of Part VII "Electrical Equipment".

**3.15.8.4** Fire fighting equipment intended for use in the area where the bow or stern loading and discharging arrangements are located is to meet the requirements of 3.3, Part V "Fire Protection".

**3.15.8.5** Communication is to be maintained between the cargo control room and the position of shore connection of the cargo hoses.

**3.15.9** Cargo piping for bow or stern loading is to be permanently installed and meet the following requirements.

**3.15.9.1** Cargo piping arranged forward or aft of the cargo area is to be laid on open parts of the deck, be clearly marked and be at least 760 mm away from the ship side.

**3.15.9.2** Only butt-welded joints with complete penetration and 100 % radiographic inspection of the welds are to be used in cargo piping outside the cargo area, irrespective of the diameter, temperature and pressure for which the piping has been designed. Flange connections may be only used within the cargo area and at cargo hose connection.

**3.15.9.3** The bow and stern loading and discharging piping is to be isolated from the cargo main by shut-off valves, spool pieces and blank flanges located in the cargo area.

**3.15.10** To remove the cargo residues after using the piping referred to in 3.15.8 special means for their purging and gas-freeing are to be provided.

Vent piping system connected with the means for re-moving the cargo residues is to be located in the cargo area.

**3.15.11** Where a part of the cargo which cannot be pumped out by cargo pump remains in the cargo tank, special means are to be provided to remove the cargo residues.

### **3.16 Pressure relief system.**

**3.16.1** All cargo tanks are to be provided with a pressure relief system arranged to send the surplus of the evaporated cargo into the vent piping system. The relieving system is to be appropriate to the design of the cargo containment system and the cargo being carried.

Hold spaces, interbarrier spaces and cargo piping which may be subject to pressures beyond their design capabilities are to be also provided with a suitable system to carry off the evaporated cargo. These systems are to be connected to a vent piping system so designed as to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, machinery and other spaces and control stations where it may create a dangerous condition.

Pressure relief systems are to be independent of other systems including the pressure control systems specified in Section 4.

**3.16.2** Each cargo tank including deck tanks shall be fitted with at least two pressure relief valves of equal capacity within the tolerances specified by the manufacturer and each shall be designed and constructed for the prescribed service.

**3.16.3** Interbarrier spaces shall be provided with pressure relief devices approved by the Register.

The required relieving capacity of pressure relief devices of interbarrier spaces surrounding cargo tanks of various designs shall be determined as follows:

**.1** the relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type A cargo tanks shall be determined in accordance with 3.19.3;

**.2** the relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type B cargo tanks may be determined in accordance with 3.19.3, however, the leakage rate shall be determined in accordance with 7.2, Part IV "Cargo Containment";

**.3** the relieving capacity of pressure relief devices for interbarrier spaces of membrane and semi-membrane tanks shall be evaluated on the basis of specific membrane/semi-membrane tank design;

**.4** the relieving capacity of pressure relief devices for interbarrier spaces adjacent to integral tanks may, if applicable, be determined in accordance with 3.19.3.

**3.16.4** The setting of the pressure relief valves is not to be higher than the vapour pressure which has been used in the design of the tank.

**3.16.5** Pressure relief valves are to be connected to the highest part of the cargo tank above deck level.

Pressure relief valves are to be arranged to prevent their becoming inoperative due to ice formation when they are closed.

Due consideration is to be given to the construction and arrangement of pressure relief valves on cargo tanks subject to low ambient temperatures.

**3.16.6** In case of cargo tanks permitted to have more than one relief valve setting this may be accomplished by:

installing two or more properly set and sealed valves and providing means as necessary for isolating the valves not in use from the cargo tank; or

installing relief valves whose settings may be changed by the insertion of previously approved spacer pieces or alternative springs or by other similar means not requiring pressure testing to verify the new set pressure.

All valve adjustments are to be sealed.

The requirements for testing and adjusting the relief valves are set out in 12.1.3.

**3.16.7** Stop valves or other means of blanking off pipes between tanks and pressure relief valves to facilitate maintenance are not to be fitted unless all the following arrangements are provided:

**.1** suitable arrangements to prevent more than one pressure relief valve being out of service;

**.2** a device which automatically and in a clearly visible way indicates which one of the pressure relief valves is out of service;

**.3** pressure relief capacities such that if one valve is out of service the remaining valves have the combined relieving capacity required by 3.6. However, this capacity may be provided by the combined capacity of all valves, if a suitably maintained spare valve is carried on board.

**3.16.8** Each pressure relief valve installed on a cargo tank is to be connected to a venting system.

**3.16.9** If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system is to be fitted for each cargo carried.

**3.16.10** Pressure relief valves and piping are to be so arranged that liquid can under no circumstances accumulate in or near the pressure relief valves.

**3.16.11** Pressure relief valves are to be positioned on the cargo tank so that they will remain in the vapour phase under conditions of 15° list and 0,015*L* trim (for *L*, see the definition in Part II "Hull" of the Rules for the Classification).

The provisions of IACS Recommendation No. 150 published in the Supplement to Rules and Guidelines of Russian Maritime Register of Shipping. IACS Procedural Requirements, Unified Interpretations and Recommendations shall be taken into consideration.



### 3.17 Additional pressure relieving system for liquid level control.

**3.17.1** Where required by 3.20.4.2, an additional pressure relieving system to prevent the tank from becoming liquid full at any time during relief under the fire exposure conditions referred to in 3.6 is to be fitted to each tank. This pressure relieving system is to consist of:

**.1** one or more relief valves set at a pressure corresponding to the gauge vapour pressure of the cargo at the reference temperature defined in 3.20.4.2;

**.2** an override arrangement, whenever necessary, to prevent its normal operation. This arrangement is to include fusible elements designed to melt at temperatures between 98 °C and 104 °C and to cause relief valves specified in 3.17.1.1 to become operable. The fusible elements are to be located in the vicinity of relief valves.

The said overriding arrangement is not to be dependent on any source of ship's power.

The additional pressure relieving system is to become operable upon loss of system power, if provided.

**3.17.2** The total relieving capacity of the additional pressure relieving system at the pressure mentioned in 3.4.1.1 is to be not less than

$$Q = FG'A^{0,82} \quad (3.17.2-1)$$

where  $Q$  = minimum required rate of discharge of air, in m<sup>3</sup>/s, at standard conditions of 0 °C and 0,1013 MPa;

$G'$  = gas factor determined by the formula

$$G' = \frac{12,4}{(L + \rho_R \cdot m)} \sqrt{ZT'/M} \quad (3.17.2-2)$$

where  $\rho_R$  = relative density of liquid phase of product at relieving conditions ( $\rho_R = 1,0$  for fresh water);

$m = -di/d\rho_R$  = gradient of decrease of liquid phase enthalpy against increase of liquid phase density, in kJ/kg, at relieving conditions.

For set pressures not higher than 0,206 MPa the values of  $m$  given in Table 3.4.2 may be used. For products not listed in Table 3.4.2 and for higher set pressures the value of  $m$  is to be calculated on the basis of the thermodynamic data of the product itself;

$i$  = enthalpy of liquid, in kJ/kg;

$T'$  = temperature in kelvins (°K) at relieving conditions, i. e. the pressure, at which the additional pressure relieving system is set;

$F$ ,  $A$ ,  $L$ ,  $D$ ,  $Z$  and  $M$  are given in 3.6.1.2.

Table 3.17.2

Product	$m$
Nitrogen	400
Ammonia, anhydrous	3400
Butadiene	1800
Butane	2000
Butylene	1900
Methane	2300
Propylene oxide	1550
Propane	2000
Propylene	1600
Vinyl chloride	900
Methyl chloride	816
Ethane	2100
Ethylene	1500

Note. The values of  $m$  are given for set pressures not higher than 0,206 MPa.

**3.17.3** If compliance with 3.17.1.1 requires changing of the setting of the relief valves, this is to be accomplished in accordance with the requirements of 3.16.6.

**3.17.4** Relief valves mentioned under 3.16.1.1 above may be the same as the pressure relief valves mentioned in 3.16, provided the setting pressure and the relieving capacity are in compliance with the requirements of 3.17.

**3.17.5** The exhaust of such pressure relief valves may be led to the venting system (see also 3.16.8, 5.2 and 5.3).

### 3.18 Vacuum protection systems.

**3.18.1** Cargo tanks designed to withstand a maximum external pressure differential exceeding 0,025 MPa and capable of withstanding the maximum external pressure differential which can be attained at maximum discharge rates with no vapour return into cargo tanks, or by operation of a cargo refrigeration system, need no vacuum relief protection.

**3.18.2** Cargo tanks for which, in accordance with 3.18.1, a vacuum relief protection is required, are to be fitted with:

two independent pressure switches for sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank, and refrigeration equipment, if fitted, at a pressure sufficiently below the maximum external pressure differential of the cargo tank; or

vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external differential pressure of the cargo tank; or

other vacuum relief systems approved by the Register.

**3.18.3** The vacuum relief valves are to admit an inert gas, cargo vapour or air to the cargo tank and are to be arranged to minimize the possibility of the entrance of water or snow.

If cargo vapour is admitted during operation of vacuum relief valves, it is to be from a source other than the cargo vapour lines.

**3.18.4** The vacuum protection system is to be capable of being tested to ensure that it operates at the prescribed pressure.

### 3.19 Size of valves.

**3.19.1** Pressure relief valves shall have a combined relieving capacity for each tank to discharge the greater of the following with not more than a 20 % rise in cargo tank pressure above MARVS:

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

**.2** vapours generated under fire exposure calculated by the formula:

$$Q = FGA^{0,82} \quad (3.19.1.2-1)$$

where  $Q$  = minimum required rate of discharge of air, in  $\text{m}^3/\text{s}$ , at standard conditions ( $0^\circ\text{C}$  and 0,1013 MPa);

$F$  = fire exposure factor for different cargo tank types:

1 — for tanks without insulation located on deck;

0,5 — for tanks above the deck when insulation is approved by the Register. Approval shall be based on the use of an approved fireproofing material, the thermal conductance of insulation, and its stability under fire exposure;

0,5 — for uninsulated independent tanks installed in holds;

0,2 — for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

0,1 — for insulated independent tanks in inerted holds or uninsulated independent tanks in inerted, insulated holds;

0,1 — for membrane and semi-membrane tanks.

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

$G$  — gas factor to be determined by the formula

$$G = \frac{12,4}{LD} \sqrt{ZT/M} \quad (3.19.1.2-2)$$

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

$L$  — latent heat of the material being vapourized at relieving conditions, in  $\text{kJ/kg}$ ;

$D$  = a constant shown in Table 3.19.1.2 depending on  $K$ ;  $K$  — the ratio of gas specific heat at the constant pressure to the specific gas heat at the constant volume. If  $K$  is not known,  $D = 0,606$  shall be used;

$Z$  = compressibility factor of the gas at relieving conditions. If not known,  $Z = 1$  shall be used;

$M$  = molecular mass of the product;

$A$  = external surface area of the tank, in  $\text{m}^2$ , for different tank types, as shown in Fig. 3.19.1.2.

The required air capacity of the protective arrangement shall be determined as per the formula:

$$M_{air} = \rho_{air} \quad \text{kg/s}, \quad (3.19.1.2-3)$$

where  $\rho_{air}$  = air density at 273,15 K and 0,1013 MPa is assumed equal to 1,293  $\text{kg/m}^3$ .

Table 3.19.1.2

<i>K</i>	<i>D</i>	<i>K</i>	<i>D</i>	<i>K</i>	<i>D</i>
1,00	0,606	1,36	0,677	1,72	0,734
1,02	0,611	1,38	0,681	1,74	0,736
1,04	0,615	1,40	0,685	1,76	0,739
1,06	0,620	1,42	0,688	1,78	0,742
1,08	0,624	1,44	0,691	1,80	0,745
1,10	0,628	1,46	0,695	1,82	0,747
1,12	0,633	1,48	0,698	1,84	0,750
1,14	0,637	1,50	0,701	1,86	0,752
1,16	0,641	1,52	0,704	1,88	0,755
1,18	0,645	1,54	0,707	1,90	0,758
1,20	0,649	1,56	0,710	1,92	0,760
1,22	0,652	1,58	0,713	1,94	0,763
1,24	0,656	1,60	0,716	1,96	0,765
1,26	0,660	1,62	0,719	1,98	0,767
1,28	0,664	1,64	0,722	2,00	0,770
1,30	0,667	1,66	0,725	2,02	0,772
1,32	0,671	1,68	0,728	2,20	0,792
1,34	0,674	1,70	0,731	—	—

**3.19.2** The back pressure in the vent lines from the pressure relief valves is to be taken into account in determining the flow capacity required in 3.19.1. The pressure drop in the vent line from the tank to the pressure relief valve inlet is not to exceed 3 % of the valve set pressure. For unbalanced pressure relief valves, the back pressure in the discharge line is not to exceed 10 % of the gauge pressure at the relief valve inlet with the vent lines under fire exposure as referred to in 3.19.1.2.

**3.19.3** The combined relieving capacity of the pressure relief devices for interbarrier spaces surrounding type A independent cargo tanks is determined by the following formula:

$$Q_{sa} = 3,4A_c \frac{\rho}{\rho_v} \sqrt{h} \quad (3.19.3)$$

where  $Q_{sa}$  = minimum required discharge rate of air, in m<sup>3</sup>/s, at standard conditions (0 °C and 0,1013 MPa);

$A_c$  = design crack opening area, in m<sup>2</sup>;

$$A_c = \frac{\pi}{4} \delta L;$$

$\delta$  = max, crack opening width, m;

$$\delta = 0,2t;$$

$t$  = thickness of tank bottom plating, in m;

$L$  = design crack length, in m, equal to the diagonal of the largest plate panel of the tank bottom, as shown in Fig. 3.19.3;

$h$  = max liquid height above tank bottom plus 100·MARVS, in m;

$\rho$  = density of product liquid phase, in kg/m<sup>3</sup>, at the set pressure of the interbarrier space relief device;

$\rho_v$  = density of product vapour phase, in kg/m<sup>3</sup>, at the set pressure of the interbarrier space relief device and a temperature of 0 °C;

MARVS = max allowable relief valve setting of the cargo tank, MPa.

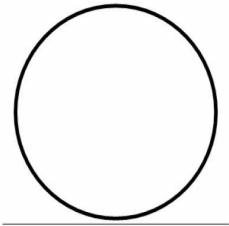
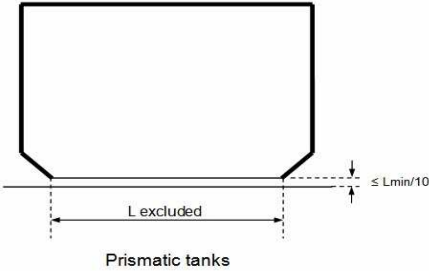
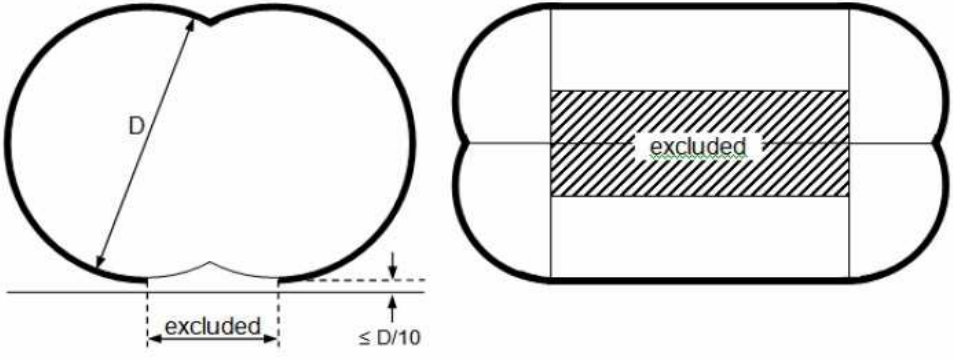
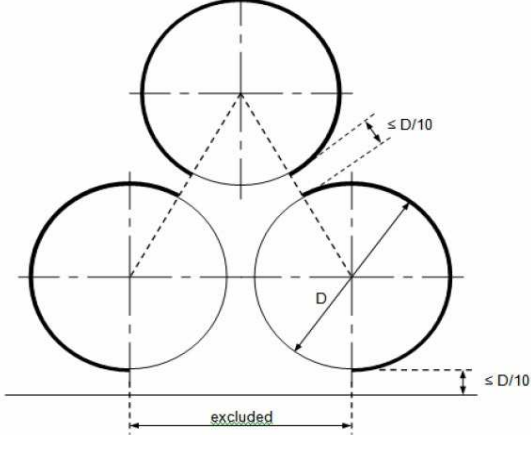
 <p>Spherical or cylindrical tanks with spherical dished ends, hemispherical or semi-ellipsoidal heads.</p> <p>External surface area <math>A</math> is assumed equal to the total area of the outer surface of the tank.</p>	 <p>Prismatic tanks</p> <p>For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is equal to or less than <math>L_{\min}/10</math>:  <math>A</math> — external surface area minus flat bottom surface area.</p> <p>For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than <math>L_{\min}/10</math>:  <math>A</math> shall be equal to the external surface area.</p> <p><math>L_{\min}</math>, for non-tapered tanks, is the smaller of the horizontal dimensions of the flat bottom of the tank. For tapered tanks, which may be used for the forward tank, <math>L_{\min}</math> is the smaller of the length and the average width.</p>
 <p>Bilobe tanks</p> <p>For bilobe tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than <math>D/10</math>, <math>A</math> shall be equal to the external surface area.</p>	
 <p>For horizontal cylindrical tanks arrangement part of the surface is excluded if the distance between the tanks and between the tanks and the support deck is less than <math>D/10</math>.</p>	

Fig. 3.19.1.2  
Area of the calculated surface

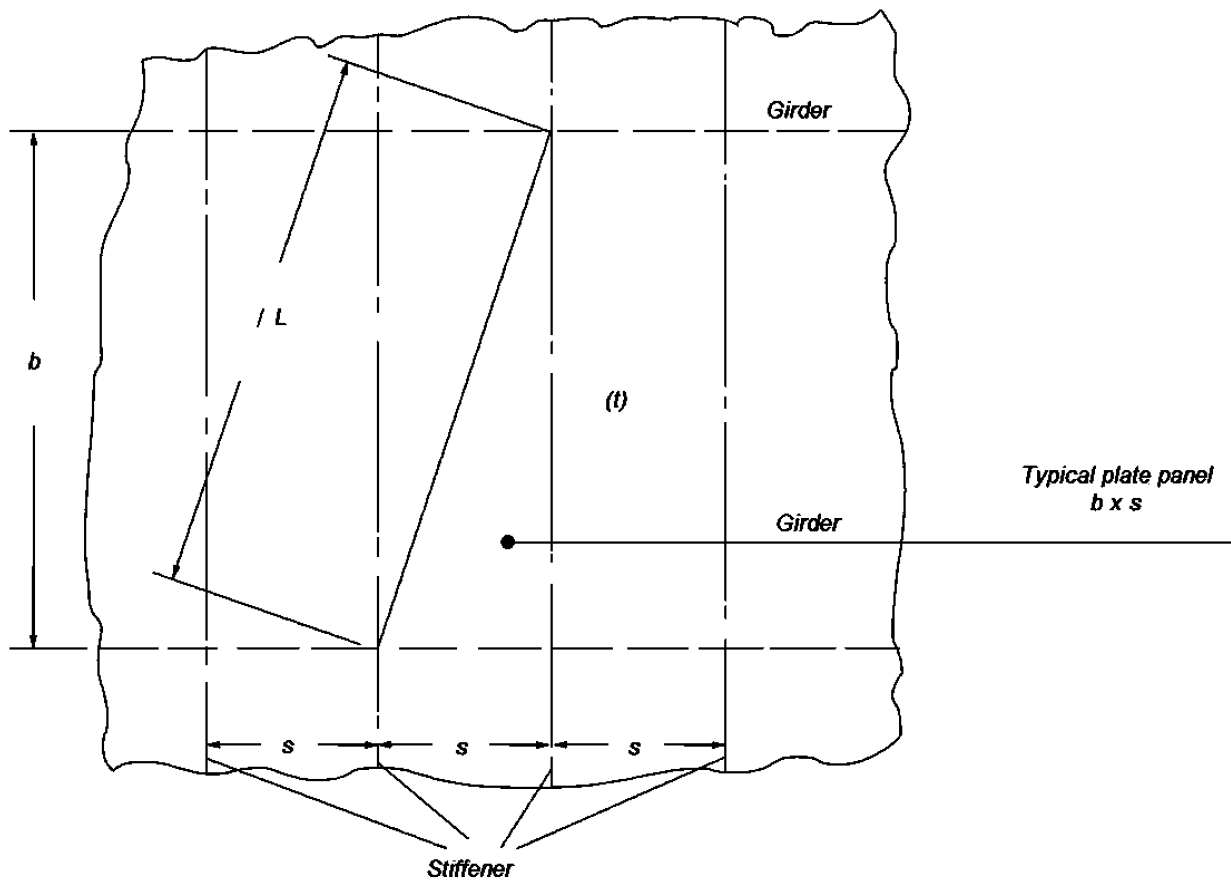


Fig. 3.19.3

### 3.20 The maximum filling limit of cargo tanks.

**3.20.1** The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:

- .1 tolerance of instrumentation such as level and temperature gauges;
- .2 volumetric expansion of the cargo between the set pressure of pressure relief valves (PRV) and the maximum allowable rise stated in 3.16.1;
- .3 an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, refer to 3.15.4.1.

The default value for the filling limit (*FL*) of cargo tanks is 98 % at the reference temperature specified in 3.20.4. Exceptions to this value shall meet the requirements of 3.20.2.

**3.20.2** A filling limit greater than the limit of 98 % may be permitted under the trim and list conditions specified in 3.16.11 and taking into account the provisions of IACS Recommendation No. 149, published in the Supplement to Rules and Guidelines of Russian Maritime Register of Shipping. IACS Procedural Requirements, Unified Interpretations and Recommendations, provided that:

- .1 no isolated vapour pockets are created within the cargo tank;
- .2 the PRV inlet arrangement shall remain in the vapour space;
- .3 allowances are made for volumetric expansion of the liquid cargo due to the pressure increase from the maximum allowable relief pressure setting (MARVS) to full flow relieving pressure in accordance with 3.17.2;
- .4 an operational margin shall be of minimum 0,1 % of tank volume;
- .5 tolerances of instrumentation such as level and temperature gauges are considered;
- .6 despite the compliance with 3.20.2.1 — 3.20.2.5, in no case shall a filling limit exceeding 99,5 % at reference temperature be permitted.

**3.20.3** The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula

$$LL = FL \frac{\rho_R}{\rho_L}, \quad (3.20.3)$$

where: *LL* — loading limit expressed in percent, which means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded;

*FL* — filling limit expressed in percent equal to the maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature specified in 3.20.4;

$\rho_R$  — relative density of cargo at the reference temperature;

$\rho_L$  — relative density of cargo at the loading temperature and pressure.

**3.20.4** For the purposes of this Chapter only, the reference temperature means:

**.1** when no cargo vapour pressure/temperature control, as referred to in Section 4, is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs;

**.2** when a cargo vapour pressure/temperature control, as referred to in Section 4, is provided, the temperature of the cargo upon termination of loading, during transportation or at unloading, whichever is the greatest. When such temperature is obtained in the cargo tank at its complete loading prior to the cargo reaching the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs, as specified in 3.16, an additional pressure relief system shall be installed in compliance with the requirements of 3.17;

**3.20.5** The Register may allow type C tanks to be loaded according to the formula in 3.20.3, with  $\rho_R$  relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during transportation, or at unloading, under the ambient design temperature conditions described in 4.1.3. This paragraph does not apply to products requiring a type 1G ship for transportation.

**3.20.6** A document shall be provided onboard the ship, specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. Pressures at which the PRVs have been set shall also be stated in the list, including those required by 3.17. The list shall be approved by the Register and shall be permanently kept on board.

**3.21 Cargo emergency shutdown (ESD) system.**

**3.21.1** A cargo emergency shutdown system shall be fitted to stop cargo flow in the event of an emergency, either internally within the ship, or during cargo transfer to ship or shore. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work (refer to 3.21.6).

**3.21.2** Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

**3.21.3** The ESD system shall be activated by the manual and automatic initiations listed in Table 3.21.7.3. Any additional initiations shall only be included in the ESD system if it can be shown that their inclusion does not reduce the integrity and reliability of the system overall.

**3.21.4** Ship's ESD systems shall incorporate a ship-shore link in accordance with recognized standard.

**3.21.5** A functional flow chart of the ESD system and related systems shall be provided in the cargo control station and on the navigation bridge.

**3.21.6 ESD valve requirements.**

**3.21.6.1** The term "ESD valve" means any valve operated by the ESD system.

**3.21.6.2** ESD valves shall be remotely operated, be of the fail-closed type (closed on loss of actuating power), be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve may be used. The manual valve shall be located adjacent to the ESD valve. Provisions shall be made to handle trapped liquid should the ESD valve close while the manual valve is also closed.

**3.21.6.3** ESD valves in liquid piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

**3.21.6.4** The closing time of the valve referred to in 3.1 and 3.2, Part VIII "Instrumentation and Automation Systems" ((i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than

$$3600U/LR, \text{ s,}$$

where  $U$  = ullage volume at operating signal level, in  $\text{m}^3$ ;

$LR$  = maximum loading rate agreed between ship and shore facility, in  $\text{m}^3/\text{h}$ .

The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the shore piping systems, where relevant.

**3.21.6.6** One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

**3.21.6.7** If cargo system valves are also ESD valves, then the requirements of this Chapter shall apply.

**3.21.7 ESD system controls.**

**3.21.7.1** As a minimum, the ESD system shall be capable of manual operation by a single control on the bridge and either in the control position required by 1.3, Part VIII "Instrumentation and Automation Systems", or the cargo control room, if installed, and no less than two locations in the cargo area.

**3.21.7.2** The ESD system shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks shall cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly. Detection may be by means of fusible elements designed to melt at temperatures between  $98\text{ }^{\circ}\text{C}$  and  $104\text{ }^{\circ}\text{C}$ , or by area fire detection methods.

**3.21.7.3** Cargo machinery that is running shall be stopped by activation of the ESD system in accordance with the cause and effect matrix in Table 3.21.7.3.

Table 3.21.7.3

ESD functional arrangements

Shutdown action →								
	Pumps		Compressor systems				Valves	Link
	Cargo pumps/cargo booster pumps	Spray/stripping pumps	Vapour return compressors	Fuel gas compressors	Reliquefaction plant*, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to ship/ shore link**
Initiation ↓								
Emergency push buttons (see 3.21.7.1)	√	√	√	1	√	√	√	√
Fire detection on deck or in compressor house*** (see 3.21.7.2)	√	√	√	√	√	√	√	√
High level in cargo tank (see 3.1 and 3.2, Part VIII "Instrumentation and Automation Systems")	√	√	√	1, 2	2, 3	2	4	√
Signal from ship/shore link (see 3.21.4)	√	√	√	1	3	N/A	√	N/A
Loss of motive power to ESD valves****	√	√	√	1	3	N/A	√	√
Main electric power failure ("blackout")	5	5	5	5	5	5	√	√
Level alarm override (see 3.1, Part VIII "Instrumentation and Automation Systems")	6	6, 7	√	2	2	2	√	√
<p><sup>1</sup> If the fuel gas compressor is used to return cargo vapour to shore, it shall be included in the ESD system when operating in this mode.</p> <p><sup>2</sup> These items of equipment can be omitted from these specific automatic shutdown initiators, provided the equipment inlets are protected against cargo liquid ingress.</p> <p><sup>3</sup> If the reliquefaction plant compressors are used for vapour return/shore line clearing, they shall be included in the ESD system when operating in that mode.</p> <p><sup>4</sup> The sensors referred to in 3.1, Part VIII "Instrumentation and Automation Systems" may be used to close automatically the tank filling valve for the individual tank where the sensors are installed, as an alternative to closing the ESD valve referred to in 3.21.6.6. If this option is adopted, activation of the full ESD system shall be initiated when the high-level sensors in all the tanks to be loaded have been activated.</p> <p><sup>5</sup> These items of equipment shall be designed not to restart upon recovery of main electric power and without confirmation of safe conditions.</p> <p><sup>6</sup> The override system permitted by 3.1, Part VIII "Instrumentation and Automation Systems" may be used at sea to prevent false alarms or shutdowns. When level alarms are overridden, operation of cargo pumps and the opening of manifold ESD valves shall be inhibited except when high-level alarm testing is carried out in accordance with 12.2.2 (see 3.21.7.4).</p> <p><sup>7</sup> Cargo spray or stripping pumps used to supply forcing vaporizer may be excluded from the ESD system only when operating in that mode.</p> <p>* Indirect refrigeration systems which form part of the reliquefaction plant do not need to be included in the ESD function if they employ an inert medium such as nitrogen in the refrigeration cycle.</p> <p>** Signal need not indicate the event initiating ESD.</p> <p>*** Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.</p> <p>**** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.</p> <p>√ – Functional requirement.</p> <p>N/A – Not applicable.</p>								

**3.21.7.4** The ESD control system shall be configured so as to enable the high-level testing required in 12.2.2, to be carried out in a safe and controlled manner. For the purpose of the testing, cargo pumps may be operated while the overflow control system is overridden. Procedures for level alarm testing and re-setting of the ESD system after completion of the high-level alarm testing shall be included in the operation manual.

**3.21.8** Additional shutdowns.

**3.21.8.1** The requirements of 3.5.2 to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or, as minimum, to stop any cargo pumps or compressors.

**3.21.8.2** An input to the ESD system from the overflow control system required by 3.2, Part VIII "Instrumentation and Automation Systems" may be provided to stop any cargo pumps or compressors' running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.



### 3.21.9 Pre-operations testing.

**3.21.9.1** Cargo emergency shutdown and alarm systems involved in cargo transfer shall be checked and tested before cargo handling operations begin.

### 3.21.10 Hot work on or near cargo containment systems.

**3.21.10.1** Special fire precautions shall be taken in the vicinity of cargo tanks and, particularly, insulation systems that may be flammable or contaminated with hydrocarbons or that may give off toxic fumes as a product of combustion.

### 3.21.11 Additional operating requirements.

**3.21.11.1** Additional operating requirements will be found in the following sections and paragraphs of the Code: 2.2.2, 2.2.5, 2.2.8, 3.8.4, 3.8.5, 5.3.2, 5.3.3.3, 5.7.3, 7.1, 8.2.7, 8.2.8, 8.2.9, 9.2, 9.3, 9.4.4, 12.1.1, 13.1.3, 13.3.6, 13.6.18, 14.3.3, 15.3, 15.6, 16.6.3, 17.4.2, 17.6, 17.7, 17.9, 17.10, 17.11, 17.12, 17.13, 17.14, 17.16, 17.18, 17.19, 17.21, 17.22.

### 3.22 Regasification plant.

**3.22.1** The regasification plant is to be designed so that a single accidental event shall not result in a critical situation. The safety system is to provide two levels of protection to prevent or minimise the effects of an equipment failure within the regasification plant. These means of protection are to be independent of each other and in addition to the control devices used in normal operation.

**3.22.2** Heating and evaporation of cargo may be arranged as direct heating or indirect heating. Means shall be provided to detect gas in heating medium and to prevent overpressure in the heating system.

Where heating medium used for LNG evaporating or heating returns outside the cargo area, the system shall provide a degasification tank in the cargo area for the heating medium input. The degasification tank shall be fitted with the gas detectors and alarm devices. The vent outlet of the degasification tank air piping shall be located in the safe position and be fitted with a flame arrestor.

**3.22.3** Means shall be provided to protect the vaporizers against freezing of heating medium.

**3.22.4** A process shut-down system (PSD) for the regasification plant shall be arranged. Initiation of PSD shall be from the monitoring system, from manual call points and remote controls. The minimum requirements to monitoring and control of the regasification plant are given in Table 3.22.4.

Table 3.22.4

Minimum required monitoring and control of regasification plant

Parameter	Alarm	Shut-down	Comments
Suction drum pressure	H/L		
Suction drum level	L	LL	PSD
Vaporizer, heating medium inlet temperature	L	LL	PSD
Vaporizer, heating medium inlet pressure	L	LL	PSD
Vaporizer, heating medium outlet temperature	L	LL	PSD
Vaporizer, LNG inlet pressure	H/L		
Vaporizer, NG outlet temperature	L	LL	PSD
Vaporizer, NG outlet pressure	H/L		
Heat exchanger, steam supply pressure	L		If steam is not direct heating medium
Heat exchanger, steam condensate return temperature	H/L		If steam is not direct heating medium
Overflow/Expansion tank in glycol loop	H	HH	If a glycol heating circuit is arranged
Liquid collector	H/L		If propane heating circuit is arranged
Gas metering for export, monitor NG flow	X	X	
Loss of power supply to control and monitoring system	X	X	
Natural gas to shore, pressure	H/L	LL	PSD
Natural gas to shore, pressure	L	LL	PSD
Vapour leakage into heating system detected	X		Gas detection in case of steam or glycol heating, pressure in case of propane heating
Activation of ship's ESD		X	PSD
Before disconnection; ensure depressurize and purge cycle completed		X	No disconnection before depressurize/purge
Gas detection in regasification units	X		
Confirmed fire in regasification area (Based on voting, i.e. two sensors confirming fire)	X	X	ESD and blow down and LNG outlet

Activation of the PSD shall:

- stop the high pressure booster pump;
- close isolation valves for the relevant regasification unit.

Separate transmitters shall be provided for control and shutdown functions. The control and safety system shall be designed to ensure that no single failure leads to a dangerous situation.

If an input signal of any parameter indicated in Table 3.22.4 is lost, the corresponding process shutdown shall be activated immediately to stop the regasification system. However, if instrument redundancy is provided, it is acceptable to continue with one healthy transmitter.

**3.22.5 Emergency shut down (ESD).**

**3.22.5.1** The requirements to emergency shutdown system given in 3.15.4 and 3.21 shall be extended to cover to the regasification plant. The ESD system shall be activated by manual call points and by fusible elements/fire detectors located in way of the regasification units in addition to 3.15.4 and 3.21.

Activation of the ESD shall:

- stop in-tank transfer pumps;
- close gas export valves;
- close manifold load valves.

**3.22.6 Depressurising system.**

**3.22.6.1** The depressurising system shall be arranged to vent all parts of the regasification unit containing more than 400 kg of hydrocarbon inventory to the vent system. The depressurising system shall ensure safe collection and disposal of hydrocarbons during normal operations and during emergency conditions. Process systems that contain significant energy shall be depressurised during an emergency situation. The rate of depressurising shall be sufficient to ensure that rupture will not occur in case of external heat input from a fire. This normally implies that blow down valves are spring return, and fail to open position. It shall be possible to activate the depressurising system manually from the control station, in addition to automatic actions initiated through the fire detection system based on voting.

**3.22.7 Pressure relief valves of regasification system.**

**3.22.7.1** If a suction drum is arranged to supply the high pressure booster pumps it shall be provided with a relief valve sized for relevant cases i.e. fire exposure when discharge pipe of buster pump is closed.

**3.22.7.2** Pressure relief valves shall be fitted in sections of the piping system where LNG may be kept in the closed volume.

**3.22.7.3** In case of relief to cargo tanks, the effect of routing high pressure LNG/NG to the cargo tank shall be documented.

**3.22.8 Vent system.**

**3.22.8.1** Special consideration shall be given with respect to release rate and the potential for liquid flow through the vent mast. In general, the fitting of a knock-out drum to be considered between the relief valves and the vent mast. The knock out drum shall be provided with high level alarm.

As an alternative, a calculation showing sufficient capacity of the vent mast to avoid any liquid release through the mast shall be carried out. Part of the regasification unit will contain high pressure LNG and part will contain high pressure gas.

Relief arrangements for both phases need to be considered.

**3.22.8.2** For permanently moored ships it may be considered disposing of gas via a flare rather than a vent. In such cases the capacity should be assessed per API RP 521 and it shall be ensured that radiation levels are within acceptable limits.

## **4 CARGO PRESSURE/TEMPERATURE CONTROL**

### **4.1 General.**

**4.1.1** Unless the ship's cargo tanks are designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, the pressure and temperature of a cargo tank shall be constantly maintained in the design value range by using one of the following methods or a combination thereof:

- .1** re-liquefaction of gas vapours;
- .2** thermal oxidizing of vapours;
- .3** pressure accumulation; and
- .4** liquid cargo refrigerating.

For some highly dangerous cargoes specified in Part X "Special Requirements", the cargo containment system shall withstand full pressure of cargo vapours at the upper ambient design temperature independently of the type of the system provided for handling the vaporizing gas.

Cargo vapours venting into the atmosphere is not permitted except in emergencies

**4.1.2** Use of at least two units for control of cargo pressure and temperature, capable of operating in every ship's mode, shall be provided onboard the ship. The capacity of each system for control of cargo pressure and temperature shall correspond to the maximum possible intensity of cargo vaporization from all LNG tanks during the normal ship's operation at the maximum design ambient temperature stated in 4.1.3, and the pressure in cargo tank not exceeding MARVS.

**4.1.3** The systems required by 4.1.1 shall be constructed, fitted and tested upon approval of the Register. Materials used in their construction shall be suitable for use with the cargoes to be carried. For normal service, the upper ambient design temperature shall be 32 °C for sea and 45 °C for air. For service in particularly hot or cold zones, these design temperatures may be increased or decreased, upon agreement with the Register.

**4.1.4** For certain highly hazardous cargoes specified in Part X "Special Requirements", the cargo tanks shall be capable of withstanding the full vapour pressure of the cargo under conditions of the upper ambient design temperatures, irrespective of any system provided for dealing with boil-off gas.

### **4.2 Refrigeration and reliquefaction systems.**

**4.2.1** A refrigeration system is to consist of one or more units capable of maintaining the required cargo pressure/temperature under conditions of the upper ambient design temperatures.

In addition to the main unit, a stand-by unit (or units) affording space capacity at least equal to the largest required unit is to be provided.

A stand-by unit is to consist of a compressor with its driving motor, control system and any necessary fittings to permit operation independently of the normal service units.

A stand-by heat exchanger is to be provided unless the normal heat exchanger for the unit has an excess capacity of at least 25 % of the largest required capacity. Separate piping systems are not required for the stand-by heat exchanger.

**4.2.2** The refrigeration system may be arranged in one of the following ways:

**.1** a direct system where evaporated cargo is compressed, condensed and returned to the cargo tanks. For certain cargoes specified in Part X "Special Requirements" this system is not to be used;

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

**.3** a combined system where evaporated cargo is compressed and condensed in a heat exchanger by refrigeration and returned to the cargo tanks. For certain cargoes specified in Part X "Special Requirements" this system is not to be used.

**4.2.3** For the carriage of two or more refrigerated cargoes which may react chemically in a dangerous manner, separate refrigeration systems shall be provided for each cargo. However, where cooling is provided by an indirect or combined system and leakage in the heat exchanger cannot cause mixing of the cargoes, separate refrigeration units are not required.

**4.2.4** Where two or more refrigerated cargoes are not mutually soluble under the condition of carriage, but their vapour pressures would be additive on mixing, measures on preventing the possibility of mixing the cargoes shall be provided in the refrigeration system.

**4.2.5** Where sea cooling water is required in the refrigeration system, a separate sea water pump used exclusively for supply of water to this system is to be provided. This pump is to have two sea suction lines, leading from sea chests, one port and one starboard.

A spare pump of adequate capacity is to be provided. This pump is also to have suction from two sea chests.

The said spare pump may be a pump of adequate capacity and pressure head, used for other services so long as its use for cooling would not interfere with any other essential service.

**4.2.6** All primary and secondary refrigerants must be compatible with each other and with the cargo with which they come into contact.

The heat exchange may take place outside either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

**4.2.7** The relevant requirements of the Rules for the Classification shall also apply to mechanisms, arrangements and equipment of reliquefaction unit for cargo vapours unless otherwise specified in the LG Rules.

### **4.3 Systems for disposing the evaporated cargo.**

**4.3.1** Where no other means of pressure reduction are provided onboard the ship, mandatory 100 % redundancy of gas flaring units shall be provided, each of them shall be designed for the maximum cargo evaporating intensity during the normal operation. Availability of three gas flaring units on the ship is permitted, each of them is designed for at least 50 % of the maximum cargo evaporating intensity during the normal operation.

**4.3.2** Alternatively to the redundancy of the gas flaring unit, the redundancy of all the main components in one gas flaring unit may be permitted:

- combustion air fan;
- dilution and cooling air fan;
- ignition spark;
- electrical sparking ignition arrangement;
- continuous burning control system;
- control and monitoring systems.

**4.3.3** It is not allowed to arrange the gas flaring unit in common machinery space. Where gas flaring unit is located in the enclosed space, such space:

- .1** shall be considered as machinery space of category A;
- .2** shall be equipped with the mechanical ventilation system having a capacity of not less than 30 air changes per hour based upon the total volume of the space and using at least two fans drawing in air from the gas-safe spaces;
- .3** ventilation intakes shall be fitted with the devices preventing ingress of moisture and foreign objects;
- .4** shall be fitted with gas detection system as stated in 11.10.

**4.3.4** Gas to the gas flaring unit shall be supplied through the ship open parts or in compliance with the requirements of Section 11 (through a double-wall piping system or the pipes in special ventilation ducts).

**4.3.5** Ahead of the piping pass-through into the space where the gas flaring unit is located, the gas supply system shall be provided with the master gas fuel valve in compliance with 11.7, and the system shall be provided with the valves in compliance with 11.6.

**4.3.6** Exhaust gas temperature after disposing in the gas flaring unit shall be at least 50 degrees lower the self-ignition temperature of the transported cargo. For this way of disposing LNG vapours, the exhaust gas temperature shall not exceed 535 °C.

**4.3.7** Combustion chamber of the gas flaring unit shall be so designed that in any operating mode the ignition spark size does not run beyond its dimensions. Temperature of the outer surfaces of the gas flaring unit case shall not exceed 220 °C even with the dilution air fan is shut down.

**4.3.8** Gas supplied to the gas flaring unit shall be at the temperature and under pressure permitted for operation of the gas burning installation. Gas pressure in the piping shall not exceed 1 MPa. Compressors, pressure vessels and heat exchangers used in the gas conditioning devices, shall meet the requirements of the relevant parts of the Rules for the Classification.

**4.3.9** The electric motors of fans for combustion, dilution and cooling, as well as the ventilating systems shall be located in a gas-safe space.

**4.3.10** The firing control system of the gas flaring unit shall be operated automatically and allow for the manual operation from the local control station.

**4.3.11** The burning installation of the gas flaring unit shall be fitted with two flare monitoring devices, and the gas supply shall be automatically stopped and they are activated. The burning installation of the gas flaring unit shall prevent the repeated supply of burning gas till the completion of the combustion chamber blowing-off.

**4.3.12** The burning installation of the gas flaring unit shall be fitted with the ignition spark or electrical spark ignition arrangement. For the ignition spark to provide continuous ignition, liquid fuel shall be used in compliance with 1.1.2, Part VII "Machinery Installations" of the Rules for the Classification. Liquid fuel supply piping for the ignition spark shall comply with the requirements of 13.2, Part VIII "Systems and Piping" of the Rules for the Classification. The ignition spark shall be fitted with a fire control device; in case of its activating the fuel supply to the ignition spark shall be automatically cut off.

**4.3.13** The firing control system of the gas firing unit shall automatically shut down supply of combustion gas in the following cases:

- shutdown of combustion air supply (fan switching off or combustion air pressure drop);
- loss of flame;
- loss of power;
- actuation of gas detection system in the space of gas flaring unit;
- actuation of gas detection system in the ventilation duct of gas fuel supply;
- loss of nitrogen pressure in the tube space of gas supply piping or loss of air pressure in the ventilation duct of gas supply piping;
- increase of exhaust gas temperature above the value stated in 4.3.7;
- reduction of gas temperature below the value permissible for normal operation of the burning installation;
- fire in the space of gas flaring unit.

**4.3.14** The firing control system of the gas flaring unit shall prevent supply of burning gas in the following cases:

- absence of signal of the ignition spark or electrical spark unit operation;
- completion of combustion chamber blowing-off.

## **5 VENT PIPING SYSTEM**

**5.1** A vent piping system is to be provided to remove surplus gas from the cargo tank pressure relief valves.

**5.2** The vent piping system is to be so constructed that the discharge of gas will be directed upwards and so arranged as to minimize the possibility of water or snow entering the system.

**5.3** The height of the vent exits is to be not less than  $B/3$  or 6 m, whichever is the greater, above the weather deck and 6 m above the working area and fore and aft gangway.

**5.4** Cargo tank pressure relief vent exits are to be arranged at a distance at least equal to ship breadth or 25 m, whichever is less, from the nearest air intake or opening to accommodation spaces, service spaces, or other gas-safe spaces.

For ships less than 90 m in length, smaller distances may be permitted by the Register. All other vent exits connected to the cargo containment system are to be arranged at a distance of at least 10 m from the nearest air intake or opening to accommodation spaces, service spaces and control stations, or other gas-safe spaces.

**5.5** All other cargo vent exits associated with cargo and not dealt with in other parts are to meet the requirements of 5.2 to 5.4.

**5.6** If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system is to be fitted for each cargo carried.

**5.7** In the vent piping system, means for draining liquid from places where it may accumulate are to be provided.

**5.8** Suitable protection screens are to be fitted on vent outlets to prevent the ingress of foreign objects.

**5.9** All vent piping is to be so designed and arranged that it will not be damaged by temperature variations to which it may be exposed, or by the ship's motions.

## **6 INERT GAS SYSTEM**

### **6.1 General.**

**6.1.1** The inerting is to provide a non-combustible environment, through the use of inert gases. The inert gas used is to be compatible chemically, under operating conditions, with the materials of construction and with the cargo carried at all temperatures likely to occur within the spaces in service.

**6.1.2** If the inert gas is stored at temperatures below 0 °C, the system is to prevent the temperature of the ship's structures from dropping below the limiting values imposed.

**6.1.3** The inert gas system is to provide inerting of interbarrier and hold spaces of the ship as well as safe gas-freeing of these spaces and areas, cargo tanks and cargo pipelines.

The inert gas system is to be also capable of delivering gas to the dead zones of the spaces protected.

**6.1.4** Arrangements are to be provided to prevent the backflow of cargo vapour into the inert gas system.

**6.1.5** The inert gas system is to be such that each space being inerted can be isolated and the pressure therein can be controlled by appropriate controls and relief valves.

**6.1.6** Inert gas which is used for the fire fighting purposes is to be stored separately and is not to be used for cargo services.

### **6.2 Inerting of hull spaces.**

**6.2.1** If the ship is intended for the carriage of flammable products, the interbarrier and hull spaces adjacent to cargo containment systems requiring a complete or partial secondary barrier, are to be inerted by dried inert gas. The inert environment is to be maintained by the shipboard gas generation plant or inert gas storage the capacity of which is to be sufficient for normal consumption of gas for at least 30 days.

**6.2.2** The interbarrier and hull spaces adjacent to cargo containment systems requiring a complete or partial secondary barrier, except as listed in Part X "Special Requirements", may be filled by dry air, if the ship is provided with an inert gas generation plant or inert gas storage the capacity of which is sufficient to inert the largest such space provided that their configuration and the capacity of the inert gas generation system ensure rapid detection of leakage from cargo tanks and the inerting thereof before a hazardous environment can develop.

Equipment is to be provided to produce a sufficient amount of dry air to satisfy the expected consumers.

**6.2.3** Spaces adjacent to the refrigerated type C independent cargo tanks are to be inerted by dry inert gas or filled with dry air. Such condition is to be maintained by the shipboard devices specified in 6.2.1, or by equipment ensuring dry air supply.

**6.2.4** In the internal insulation tanks, the interbarrier spaces as well as spaces between the secondary barrier and inner hull or the independent tank structure fully filled by the insulation complying with the requirements of 19.3 and 19.4, Part IV "Cargo Containment" need not be inerted.

### **6.3 Inerting of cargo tanks and systems.**

**6.3.1** The inert gas system is to minimize the possibility of flammable mixture formation in cargo tanks at any gas-freeing stage.

**6.3.2** The cargo piping systems are to be capable of becoming free of inert gas and of being purged as indicated in 6.3.1.

**6.3.3** To monitor the purging and gas-freeing process, each cargo tank is to be fitted with gas sampling arrangements.

Gas sampling connections are to be valved and fitted above the upper deck.

The gas sampling connection is to be fitted with at least two isolating valves. Use of threaded and union couplings is to be reduced to the minimum in the gas sampling pipeline and be avoided in the pipelines with an outside diameter more than 25 mm.

The open method of sampling is to be only allowed for the cargoes, which sample remains may be discharged to the atmosphere. For other cargoes an arrangement for the sample safe return into a cargo tank is to be provided.

**6.3.4** The inert gas may be supplied from both the shipboard and shore-based facility.

### **6.4 Inert gas generation plant.**

**6.4.1** The plant is to produce inert gas with an oxygen content at no time greater than 5 % by volume subject to the requirements of Part X "Special Requirements".

A continuous-reading oxygen content meter with an alarm set at a maximum of 5 % oxygen content by volume subject to the requirements of Part X "Special Requirements" is to be fitted to the inert gas supply from the plant.

Liquefied nitrogen used as inert gas and produced by an onboard process of fractional distillation of the air, before entering the shipboard storage vessel, is to be monitored for traces of oxygen to avoid possible oxygen enrichment of the gas when released for inerting purposes.

**6.4.2** The inert gas system is to be fitted with pressure controls and monitoring arrangements appropriate to the cargo containment system.

An arrangement is to be provided to prevent ingress of cargo into the inert gas system.

**6.4.3** Spaces containing inert gas generation plants are not to have direct access to accommodation, service spaces and control stations. The plants may be located in the machinery spaces. Where the plants are arranged outside the cargo area, two non-return valves or equivalent devices required by 6.4.2 are to be fitted in the inert gas supply main within the cargo area.

The inert gas main is not to pass through accommodation, service spaces and control stations.

**6.4.4** Flame burning equipment for generating inert gas are not to be located within the cargo area.

Special consideration is to be given to the location of inert gas generating equipment using the catalytic combustion process.

## **7 BILGE AND BALLAST SYSTEMS**

**7.1** Where cargo is carried in cargo tanks not requiring a secondary barrier, hold spaces are to be provided with suitable drainage arrangements. These arrangements are to be independent and not connected with the machinery space.

Means of detecting any leakage are to be provided for such spaces.

**7.2** Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through adjacent ship structure are to be provided.

The suction is not to be led to pumps inside the machinery space.

Means of detecting such leakage are to be provided.

**7.3** The interbarrier space is to be provided with drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements are to provide for the return of any cargo leakage to cargo tanks.

**7.4** Suitable independent arrangements are to be provided for drainage of pump and compressor rooms.

**7.5** In case of internal insulation tanks, means of detecting leakage and drainage arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structure which are completely filled by insulation material complying with the requirements of 19.3 and 19.4, Part IV "Cargo Containment".

**7.6** Ballast tanks, fuel oil tanks and gas-safe spaces may be connected to pumps in the machinery space.

Bottom pipe tunnels may be connected to pumps in the machinery space, provided the connections are led directly to the pumps and the discharge from pumps led directly overboard with no valves or manifolds in either line which could connect the line from the bottom tunnel to lines serving gas-safe spaces.

Pump vents serving dry bottom ballast pipe tunnels shall not be open to the machinery space.

## **8 VENTILATION SYSTEM**

### **8.1 Spaces required to be entered during normal cargo handling operations.**

**8.1.1** Electric motor rooms, cargo compressor and pump-rooms, other enclosed spaces which contain cargo handling equipment and similar spaces in which cargo handling operations are performed are to be fitted with mechanical ventilation systems independent of other ventilation systems and capable of being controlled outside such spaces.

Provision is to be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such ventilation is to be placed outside the compartment.

**8.1.2** Mechanical ventilation inlets and outlets are to be arranged to ensure sufficient air movement through the space to avoid the accumulation of flammable or toxic vapours and to ensure a safe working environment.

The ventilation system is to have a capacity of not less than 30 air changes per hour based upon the total volume of the space. As an exception, gas-safe cargo control rooms may have 8 changes of air per hour.

**8.1.3** Ventilation systems of spaces are to be fixed and, if of the negative pressure type, permit extraction from both the upper and lower parts of the spaces, depending on the density of the vapours of the products carried.

**8.1.4** In rooms housing electric motors driving cargo compressors or pumps, spaces containing inert gas generators, cargo control rooms if considered as gas-safe spaces and other gas-safe spaces within the cargo area the ventilation is to be of positive pressure type and is to ensure positive pressure in these spaces.

**8.1.5** In cargo compressor and pump-rooms and in cargo control rooms if considered gas-dangerous, the ventilation is to be of the negative pressure type.



**8.1.6** Ventilation exhaust ducts from gas-dangerous spaces shall discharge upwards. The outlets shall be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space and they shall be located at least 10 m in the horizontal direction from ventilation intakes and openings to accommodation spaces, service spaces, control stations and other gas-safe spaces.

**8.1.7** Ventilation intakes are to be so arranged as to minimize the possibility of re-cycling hazardous vapours from any ventilation discharge opening.

**8.1.8** Ventilation ducts from gas-dangerous spaces are not to be led through machinery, accommodation and service spaces or control stations, except as specified in Section 10.

**8.1.9** Electric motors driving fans are to be placed outside the ventilation ducts if the carriage of flammable products is intended.

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, for gas-dangerous spaces are to be of non-sparking construction complying with the requirements of 5.3.3, Part IX "Machinery" of the Rules for the Classification.

**8.1.10** Spare impellers together with shaft, bearings and electric motors, one of each type, are to be carried for each type of fan used in cargo areas.

**8.1.11** Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts.

## **8.2 Spaces not normally entered.**

**8.2.1** Hold spaces, interbarrier spaces, void spaces, cofferdams, spaces containing cargo piping and other spaces where cargo vapours may accumulate, are to be capable of being ventilated to ensure a safe environment when entry into the spaces is necessary. Where a permanent ventilation system is not provided for such spaces, approved means of portable mechanical ventilation are to be provided.

Where necessary, essential ventilation ducting in hold spaces and interbarrier spaces is to be permanently installed.

Fans or blowers are to be clear of personnel access openings, and are to comply with the requirements of 8.1.9.

## **8.3 Ventilation of other spaces.**

**8.3.1** The ventilation inlets are not to face the cargo area. They are to be located on the end bulkhead not facing the cargo area, bow or stern loading and discharging arrangements and/or on the side of the superstructure at a distance equal to  $L/25$ , but not less than 3 m, from the bulkhead facing the cargo area. This distance may not to exceed 5 m.

Consideration is to be given to the arrangement of ventilation inlets in relation to cargo piping, vent piping and exhaust piping of arrangements operating on liquefied gas.

The Register may allow relaxation from the said requirements for ships intended for the carriage of cargoes which are not toxic or ignition hazardous as well as for small ships where these requirements cannot be fulfilled.

**8.3.2** All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices ensuring gastightness.

When carrying toxic products, they shall be capable of being operated from inside the space. However, in this case:

**.1** the requirement for fitting air intakes and openings with closing devices operated from inside the space for toxic products need not apply to spaces not normally manned, such as deck stores, forecastle stores, workshops. In addition, the requirement does not apply to cargo control rooms located within the cargo area;

**.2** the closing devices need not be operable from within the single spaces if centralized control is provided from a centralized control station;

**.3** engine room casings, cargo machinery spaces, electric motor rooms and steering gear compartments are considered as spaces not normally manned and not covered by this paragraph and therefore the requirement for closing devices need not be applied to these spaces;

.4 the closing devices shall give a reasonable degree of gas tightness. Steel fire-flaps without gaskets/seals shall not be considered satisfactory;

.5 regardless of these requirements, closing devices for all air intakes and outlets operable from outside the space shall be provided in accordance with 12.1.7, Part VIII "Systems and Piping" of the Rules for the Classification.

**8.3.3** The air lock space is to be provided with mechanical ventilation of positive pressure type from the gas-safe space to maintain positive pressure in relation to the gasdangerous zone on the weather deck. The ventilation is to have a capacity to give at least 30 air changes per hour.

**8.3.4** For ships with regasification unit the ventilation openings mentioned in 8.3.2 shall be provided with closing arrangements to be remotely activated from the bridge and CCR.

**8.4** In machinery spaces of category A where gas is used as fuel, an independent mechanical ventilation is to be provided to ensure freedom from dead zones.

## **9 CARGO PUMP ROOMS AND CARGO COMPRESSOR ROOMS**

**9.1** Cargo pump-rooms and cargo compressor rooms are to be situated above the weather deck and located within the cargo area. The fire integrity of bulkheads and decks of these spaces is to comply with the requirements of 2.4.2, Part VI "Fire Protection" of the Rules for the Classification imposed on pump rooms.

**9.2** Where pumps and compressors are driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of gas seal are to be fitted in way of the bulkhead or deck. Cargo pumps and compressors are to be fitted with temperature sensors of the seals of shafts passing through the bulkhead or deck, of the bearings and pump casings.

**9.3** Arrangements of cargo pump rooms and cargo compressor rooms are to be such as to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injure, to allow unconscious personnel to be removed. All valves necessary for cargo handling are to be readily accessible to personnel wearing protective clothing.

## **10 CARGO CONTROL ROOMS**

**10.1** All cargo control rooms are to be above the weather deck and, as a rule, located in the cargo tank zone.

Cargo control rooms may be located within accommodation spaces, service spaces or control stations provided the following conditions are complied with:

the cargo control room is considered as a gas-safe space;

if the cargo control room has access to the accommodation and service spaces, the entrance from the cargo tank zone is to comply with the requirements of 1.6, Part II "Ship Arrangement" and 8.3.1 of this Part or if the cargo control room has no access to the above spaces, air intakes and openings are to comply with the requirements of 1.7 and 1.12, Part II "Ship Arrangement" and 8.3.1 of this Part.

**10.2** If the cargo control room is considered as gas-safe space, instrumentation is to be, as far as possible, by indirect reading system and is to be in any case designed to prevent any escape of gas into the atmosphere of that space.

Location of gas detectors within the cargo control room will not violate the gas-safe space if installed in accordance with Section 6, Part VIII "Instrumentation and Automation Systems".

**10.3** If the cargo control room for ships carrying flammable cargoes is considered as gas-dangerous space, sources of ignition are to be excluded.

Consideration is to be given to the safety characteristics of any electrical installations in the cargo control rooms.

## **11 USE OF CARGO AS FUEL**

**11.1** Liquefied methane is the only cargo whose vapour or boil-off gas may be utilized as a fuel in boilers, inert gas generators, combustion engines and gas turbines.

Machinery spaces of category A in which gas fuel is utilized are to be fitted with gas detectors complying with the requirements of Section 6, Part VIII "Instrumentation and Automatic System".

**11.2** Gas fuel piping is not to pass through accommodation spaces, service spaces and control stations.

Gas fuel piping may pass through or extend into other spaces provided they fulfil the following:

**.1** the gas fuel 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 and automatic shutdown of gas fuel shall be provided in the event of loss of inert gas pressure between the pipes;

**.2** the gas fuel piping is to be installed within a ventilated pipe or duct.

The air space between the gas fuel piping and inner wall of this pipe or duct is to be equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour.

Suitable alarms and automatic shutdown of gas fuel shall be provided if the required air flow is not established by the ventilation system.

The ventilation system is to be arranged to maintain a pressure less than the atmospheric pressure.

The fan motors are to be placed outside the ventilated pipe or duct.

The ventilation outlet is to be placed in a position where no explosive gas-air mixture may be ignited.

The ventilation inlets are to be so arranged that no gas or gas-air mixture can be taken into the ventilation system.

The ventilation is to be always in operation when there is gas fuel in the piping.

Continuous gas detection is to be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with 11.10.

The exhaust ventilation fan for such duct is to be so arranged as to shut down the gas fuel supply to the machinery space if the required air flow is not established and maintained.

The electrical equipment arranged inside double-wall piping is to be of intrinsically safe type.

**11.3** If a gas leak occurs, the gas fuel supply is not to be restored until the leak has been found and repaired. Instructions to this effect are to be placed in a prominent position in the machinery spaces.

**11.4** The double-wall piping systems or the ventilated pipe or duct provided for the gas fuel piping are to terminate at the ventilation hood or casing required by 11.5.

**11.5** A ventilation hood or casing is to be provided for the areas occupied by flanges, valves, etc., and for the gas fuel piping, at the gas fuel utilization units.

If this ventilation hood or casing is not served by the exhaust ventilation fan as specified in 11.2.2, then it is to be equipped with an exhaust ventilation system and continuous gas detection is to be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with 11.10.

The exhaust ventilation fan is to be so arranged as to shut down the gas fuel supply to the machinery space if the exhaust ventilation does not ensure the required air flow.

The ventilation hood or casing is to be installed or mounted to permit the ventilating air to sweep across the gas utilization unit and be exhausted at the top of the ventilation hood or casing.

**11.6** Each gas utilization unit is to be provided with a set of three automatic valves. Two of these valves are to be in series in the gas fuel pipe to the consuming equipment. The third 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. The shut-off valves are to be arranged for manual reset.

These valves are to be arranged so that failure of the necessary forced draught, loss of flame on boiler burners, abnormal pressure in the gas fuel supply line, or failure of the hydraulic valve control actuator will cause the two gas fuel valves which are in series to close automatically and the vent valve to open automatically.

One of the valves in series and the vent valve can be incorporated into one valve body so arranged that, when one of the above conditions occurs, flow to the gas utilization unit will be blocked and the vent opened.

**11.7** A master gas fuel valve is to be installed outside the machinery space. The valve is to be arranged so as to close automatically if:

leakage of gas fuel is detected;

conditions stated in 11.2.1 are fringed;

engine crankcase oil mist concentration or engine bearing monitoring sensor is actuated;

It is recommended that the master gas fuel valve will be closed automatically when the gas valves referred to in 11.6 are actuated.

**11.8** Provision is to be made for inerting and gas-freeing that portion of the gas fuel piping system located in the machinery space.

**11.9** The ventilation inlet and discharge for the required ventilation systems is to be respectively from and to a safe location.

**11.10** Gas detection systems referred to in 11.2 and 11.5 are to activate the alarm at 30 % of the lower flammable limit and shut down the gas fuel supply to the machinery space before the gas concentration reaches 60 % of the lower flammable limit.

**11.11** All items of the gas fuel system are to be approved by the Register.

**11.12** Gas fuel piping in machinery spaces is to comply with the requirements of 13.12, Part VIII "Systems and Piping" of the Rules for the Classification and Sections 2 and 12 of the present Part as far as applicable. The piping is to have welded joints. Those parts of the gas fuel piping which are not enclosed in ventilated pipe or duct according to 11.2 and are on the open deck outside the cargo area are to have full penetration butt-welded joints and are to be fully radiographed.

**11.13** If the cargo carried is utilized as fuel, a gas make-up plant and related storage tanks are to be provided on board the ship.

**11.13.1** All equipment (heaters, compressors, filters, etc.) for making up the gas for its use as fuel and related storage tanks are to be located in the cargo area. If the equipment is in an enclosed space, the requirements of 3.1, Part V "Fire Protection", 8.1 of the present Part and Section 6, Part VIII "Instrumentation and Automation Systems" are to be complied with.

**11.13.2** The compressors are to be capable of being automatically stopped before the vacuum relief valves of the tanks are actuated.

The compressors are to be capable of being remotely stopped from a position which is readily accessible, and also from the engine room.

The compressors are to be provided with a device for automatic shut down when the automatic shut-off valves referred to in 11.6 and 11.7 are actuated. These valves are to be arranged for manual reset.

Volumetric compressors are to be fitted with pressure relief valves discharging into the suction line of the compressor. The size of the pressure relief valves is to be determined in such a way that under any circumstances the maximum pressure does not exceed by more than 10 % the maximum working pressure.

**11.13.3** If the heating medium for the gas fuel evaporator or heater is returned to spaces outside the cargo area it is first to go through a degassing tank. The degassing tank is to be located in the cargo area. Provisions are to be made to detect and alarm the presence of gas in the tank. The vent outlet of the tank is to be in a safe position and fitted with a flame screen.

**11.14** Boilers which use the cargo as fuel are to comply with the following requirements.

**11.14.1** Each boiler is to have a separate uptake.

**11.14.2** Combustion chambers of boilers are to be of suitable form such as not to present pockets where gas may accumulate.

**11.14.3** The burning installations are to be suitable to burn either oil fuel or methane alone or oil and methane simultaneously.

Transfer from gas to oil burning is not to cause change of the boiler operating mode.

The gas burning installation is to be provided with a pilot burner operating on oil fuel.

The burning installations are to be interlocked and equipped with non-disconnectable protective devices as specified in 5.3.2 to 5.3.4, Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification.

**11.14.4** On the pipe of each gas burner a manually operated shut-off valve is to be fitted.

An installation is to be provided for purging the gas supply piping to the burners by means of inert gas or steam, after the extinguishing of these burners.

**11.14.5** The controls, regulators, interlocking, protective devices and alarms of the automated burning installations are to comply with the requirements of 4.3, Part XV "Automation" of the Rules for the Classification.

**11.15 Special requirements for gas-fired internal combustion engines.**

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

**11.15.1 Arrangement.**

**11.15.1.1** When gas is supplied in a mixture with air through a common manifold, flame arrestors shall be installed before each cylinder head.

**11.15.1.2** Each engine shall have its own separate exhaust.

**11.15.1.3** The exhausts shall be configured to prevent any accumulation of unburnt gaseous fuel.

**11.15.1.4** 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 shall be fitted with suitable pressure relief systems. Pressure relief systems shall lead to a safe location, away from personnel.

**11.15.1.5** Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

**11.15.2 Combustion equipment.**

**11.15.2.1** Prior to admission of gas fuel, correct operation of the pilot oil injection system on each unit shall be verified.

**11.15.2.2** 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 gas supply valve, this shall be automatically shut off and the starting sequence terminated. It shall be ensured that any unburnt gas mixture is purged from the exhaust system.

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

**11.15.2.4** In the case of unstable operation on engines with the arrangement in 11.15.2.3 when gas firing, the engine shall automatically change to oil fuel mode.

**11.15.3 Safety.**

**11.15.3.1** During stopping of the engine, the gas fuel shall be automatically shut off before the ignition source.

**11.15.3.2** Arrangements shall be provided to ensure that there is no unburnt gas fuel in the exhaust gas system prior to ignition.

**11.15.3.3** Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection (refer to Section 6, Part VIII "Instrumentation and Automation Systems").

**11.15.3.4** Provision shall 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 shall be in accordance with the requirements of Section 2, Part VII "Electrical Equipment".

**11.15.3.5** A means shall 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 shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of Section 2, Part VII "Electrical Equipment".

## 12 TESTING

### 12.1 Tests of piping components and pumps prior to installation on board.

#### 12.1.1 Valves.

**12.1.1.1** Tests of piping valves shall comply with the requirements of 21.1, Part VIII "Systems and Piping" of the Rules for the Classification. Moreover, valves of cargo system and piping containing cargo or its vapours shall be subjected to the prototype and unit production testing, as stipulated in 12.1.1.1.1 and 12.1.1.1.2.

##### 12.1.1.1.1 Type testing of piping components.

**12.1.1.1.1.1** Each size and type of valve intended to be used at a working temperature below  $-55\text{ }^{\circ}\text{C}$  shall be approved through design assessment and prototype testing. Prototype testing for all valves to the minimum design temperature or lower and to a pressure not lower than the maximum design pressure foreseen for the valves shall be witnessed in the presence of the RS surveyor. Flow and capacity of pressure relief valves covered by 3.16 shall be certified by the Administration or the Register acting on its behalf. For other types of valves, the manufacturer shall certify the flow properties of the valves based on tests carried out according to recognized standards. Prototype testing shall include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure, and cryogenic testing consisting of valve operation or safety valve set pressure. In addition, for all valves other than safety valves, a seat and stem leakage test at a pressure equal to 1,1 times the design pressure shall be conducted.

The following type tests shall be conducted:

**.1** each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and temperatures, at intervals, up to the rated design pressure of the valve. During the testing, satisfactory operation of the valve shall be verified;

**.2** the flow or capacity shall be certified to a recognized standard for each size and type of valve;

**.3** pressurized components shall be pressure tested to at least 1,5 times the rated pressure; and

**.4** for emergency shutdown valves, with materials having melting temperatures lower than  $925\text{ }^{\circ}\text{C}$ , the type testing shall include a fire test. ESD valves, with materials having melting temperatures lower than  $925\text{ }^{\circ}\text{C}$ , do not include emergency shutdown valves which use such materials only in components such as rubber handle covers where failure would not cause deterioration of shell or seat tightness intrinsically.

##### 12.1.1.1.2 Unit production testing.

**12.1.1.1.2.1** All valves are to be tested at the plant of manufacturer in the presence of the surveyor to the Register. For valves used for isolation of instrumentation in piping not greater than 25 mm, unit production testing need not be witnessed by the surveyor. Records of testing shall be available for review. Testing is to include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to 1,1 times the design pressure for all valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10 % of each type and size of valve for all valves other than safety valves intended to be used at a working temperature below  $-55\text{ }^{\circ}\text{C}$ . The set pressure of safety valves is to be tested at ambient temperature. Opening pressure of the pressure relief valve is to be tested at temperature  $+25\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ .

As an alternative to the above, if so requested by the relevant manufacturer, the certification of a valve may be issued subject to the following:

**.1** the valve has been approved as required by 12.1.1.1.1 for valves intended to be used at a working temperature below  $-55\text{ }^{\circ}\text{C}$ ;

**.2** the manufacturer has a recognized quality system that has been assessed and certified by the Register subject to periodic audits;

**.3** the quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure and seat and stem leakage test at a pressure equal to 1,1 times the design pressure for valves other than safety valves at working temperature. Opening pressure of the pressure relief valve shall be tested at temperature  $+25\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ . The manufacturer is to maintain records of such tests;

.4 cryogenic testing consisting of valve operation and leakage verification for a minimum of 10 % of each type and size of valve for valves other than safety valves intended to be used at a working temperature below  $-55^{\circ}\text{C}$  in the presence of the surveyor to the Register.

**12.1.2 Expansion bellows.**

**12.1.2.1** The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and on those installed within the cargo tanks:

.1 elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than 5 min;

.2 pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer, without permanent deformation.

Based on the materials used, the Register may require testing at the minimum design temperature;

.3 a cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service.

Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature;

.4 a cyclic fatigue test (ship deformation) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2000000 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.

**12.1.3 Pressure relief valves.**

**12.1.3.1** The pressure relief valves installed on cargo tanks according to 3.3.2 shall be tested to verify the relieving capacity required by 3.6. Additionally each pressure relief valve shall be tested to ensure that it opens at the prescribed pressure setting, with an allowance not exceeding:

$\pm 10\%$  for 0 to 0,15 MPa (0 to 1,5 kgf/cm<sup>2</sup>);

$\pm 6\%$  for 0,15 to 0,3 MPa (1,5 to 3,0 kgf/cm<sup>2</sup>);

$\pm 3\%$  for 0,3 MPa (3 kgf/cm<sup>2</sup>) and above.

The pressure relief valves shall be set and sealed by the surveyor to the Register. An appropriate entry shall be made in the report issued to the ship, the report shall also indicate MARVS.

**12.1.4 Cargo pumps.**

**12.1.4.1 Prototype testing.**

**12.1.4.1.1** Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the surveyor to the Register. In lieu of prototype testing, satisfactory in-service experience of an existing pump design approved by the Register submitted by the manufacturer may be considered. Prototype testing is to include a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but is to be of sufficient length to include at least one bearing and sealing arrangement. After completion of tests, the pump is to be opened out for examination.

**12.1.4.2 Unit production testing.**

**12.1.4.2.1** All pumps are to be tested at the plant of manufacturer in the presence of the surveyor to the Register. Testing is to include hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.

As an alternative to the above, if so requested by the relevant manufacturer, the certification of a pump may be issued subject to the following:

- .1 the pump has been approved as required by 12.1.4.1;
- .2 the manufacturer has a recognized quality system that has been assessed and certified by the Register subject to periodic audits;
- .3 the quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. The manufacture is to maintain records of such tests.

**12.2 Testing of cargo systems and piping on board.**

**12.2.1** After assembly, all cargo and process piping is to be subjected to a hydrostatic test to at least 1,5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board are to be hydrostatically tested to at least 1,5 the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing means are to be submitted to the Register for approval. After assembly on board, each cargo and process piping system is to be subjected to a leak test (by air, halides, etc.) to a pressure depending on the leak detection method applied.

**12.2.2** All piping systems including valves, fittings and associated equipment for handling cargo or vapours are to be tested under normal operating conditions not later than at the first loading operation.

**12.2.3** Piping, which does not contain liquid cargo or its vapours, is to be tested in compliance with 21.2, Part VIII "Systems and Piping" of the Rules for the Classification.



## **PART VII. ELECTRICAL EQUIPMENT**

### **1 GENERAL**

#### **1.1 Application.**

**1.1.1** The requirements of this Part are applicable to electrical installations and individual kinds of electrical equipment of ships intended for the carriage of liquefied gases and other products in bulk specified in 1.1, Part I "Classification" of the LG Rules and supplement the requirements of Part XI "Electrical Equipment" of the Rules for the Classification.

**1.1.2** In addition to the electrical equipment listed in 1.3.2, Part XI "Electrical Equipment" of the Rules for the Classification, subject to survey on board the ship is the electrical equipment of:

- .1** cargo containment system;
- .2** gas re-liquefaction plants;
- .3** inert gas system;
- .4** cargo pressure/temperature control system;
- .5** liquefied gas refrigeration plant drives and control systems;
- .6** cargo pumps and compressors;
- .7** ventilation systems of dangerous spaces and air locks;
- .8** gauging, alarm and indication systems for:
  - .8.1** liquid level in cargo tanks;
  - .8.2** temperature in cargo piping;
  - .8.3** pressure in cargo tanks and cargo piping;
  - .8.4** pressure in ventilation systems for pressurization of air locks, spaces, safe-type electrical equipment enclosures;
  - .8.5** cargo (gas) vapour concentration in controlled spaces and areas;
  - .8.6** cargo leakage;
  - .8.7** presence of water in interbarrier spaces;
  - .8.8** explosive concentration and high toxicity level of gases;
  - .9** automatic and remote shutdown systems for driving motors;
  - .10** remote control systems of hull structure heater valves.

**1.1.3** In addition to 1.3.3, Part XI "Electrical Equipment" of the Rules for the Classification, the electrical equipment of gas carriers specified in 1.1.2 of the present Part is subject to survey during manufacture.

#### **1.2 Definitions and explanations.**

##### **1.2.1 Hazardous zones and spaces.**

**Hazardous zone** means an area where an explosive gas mixture is or may be expected to be present, in quantities such as to require special protection measures during the design, manufacture and operation of electrical installations.

Depending on the frequency and duration of the presence of an explosive gas atmosphere, hazardous zones are divided into:

zone "0" being an area in which an explosive gas atmosphere (a mixture of combustible substances in the form of gas, steam or fog) is present often, continuously or is present for long periods;

zone "1" being an area in which explosive gas atmosphere (a mixture of combustible substances in the form of gas, steam or fog) is likely to occur under normal operating conditions;

zone "2" being an area in which an explosive gas atmosphere (a mixture of combustible substances in the form of gas, steam or fog) is not likely to occur under normal operating conditions, and if does occur, it exists for a short period only.

**1.2.2** Spaces containing gas detectors devices and spaces for utilization of gas fuel as required by Section 11, Part VI "Systems and Piping" are not to be considered as hazardous spaces.

## **2 ELECTRICAL INSTALLATION**

### **2.1 General.**

**2.1.1** Electrical installations are to be such as to minimize the risk of fire and explosion from flammable products.

**2.1.2** Electrical equipment or wiring is not to be installed in gas-dangerous spaces or zones unless essential for operation in these spaces and zones provided the requirements set forth in this Part are complied with.

**2.1.3** Where electrical equipment is installed in gas-dangerous spaces or zones, it is to satisfy the requirements of the LG Rules and IEC 60092-502 "Electrical Installation in Ships — Tankers — Special features", be approved by the Register and permitted (i.e. certified) for operation in the explosive atmosphere by the relevant (competent body).

**2.1.4** Electrical generation and distribution systems, and associated control systems shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by Part VI "Systems and Piping", and hull structure temperature, as required by Part IV "Cargo Containment", within normal operating limits. The designer shall develop and submit for approval the procedure for failure mode and effects analysis (FMEA) (in compliance with IEC 60812).

### **2.2 Electrical equipment in hazardous spaces and zones.**

**2.2.1** To facilitate the selection of suitable electrical equipment and devices, hazardous areas and spaces shall be divided into zones, as specified in IEC 60092-502 "Electrical installations in ships — Tankers — Special features".

**2.2.1.1** Only safe-type electrical equipment certified by the relevant competent body for the appropriate type of protection may be fitted in gas-dangerous spaces and zones as specified below. Automatic isolation of non-certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.

**2.2.1.2** Only intrinsically safe electrical equipment and wiring may be fitted in all gas-dangerous spaces and zones "0".

### **2.2.2 Cargo containment systems.**

**2.2.2.1** Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements are to be made to automatically shut down the motors in the event of liquid level falling below the allowable value. This may be accomplished by sensing low pump discharge pressure, low motor current, or low liquefied gas level.

This shutdown is to be alarmed at the cargo control station. Cargo pump motors are to be provided with arrangements to isolate them from their electrical supply (including feeders). These arrangements are to be actuated in advance for the period of gas-freeing operations.

### **2.2.3 Cargo spaces and certain other spaces.**

**2.2.3.1** In cargo spaces (tanks) where cargo is carried in a cargo containment system requiring a secondary barrier, supply cables for submerged cargo pump motors may be installed.

**2.2.3.2** In cargo spaces (tanks) where cargo is carried in a cargo containment system not requiring a secondary barrier and in spaces separated from cargo containment spaces by a single gastight bulkhead, the following may be installed:

through runs of cables;

lighting fittings with pressurized enclosures (*Exp*) or of flameproof type (*Exd*). The lighting system is to comply with the requirements specified in Section 9;

electrical level gauges, log and echo sounder devices and impressed current cathodic protection system anodes (electrodes). These devices are to be housed in gastight enclosures.

In spaces separated from cargo spaces described in this paragraph by gastight bulkheads the following may be installed:

safe-type motors for remote valve operation for cargo or ballast systems;

safe-type general alarm audible indicators.

#### **2.2.4 Cargo pump and cargo compressor rooms.**

**2.2.4.1** Lighting fittings are to have pressurized enclosures (*Exp*) or are to be of flameproof type (*Exd*). The lighting system is to be supplied by at least two feeders. All switches and protective devices are to interrupt all poles or phases and be located in gas-safe spaces.

**2.2.4.2** Electric motors for driving cargo pumps or cargo compressors are to be separated from the cargo pump (compressor) rooms by a gastight bulkhead or deck.

Flexible couplings or equivalent means of maintaining alignment are to be fitted to the shafts between the driven equipment and its motors and, in addition, suitable glands are to be provided where the shafts pass through the gastight bulkhead or deck. Such electric motors and associated equipment (starters, etc.) are to be located in gas-safe spaces.

**2.2.4.3** Where operational or structural requirements are such as to make it impossible to comply with the method described in 2.2.4.2, motors of the following certified safety types may be installed: of increased safety (*Exe*), of flameproof type (*Exd*), with pressurized enclosures (*Exp*).

**2.4.4.4** General alarm audible indicators are to be of flameproof type (*Exd*).

#### **2.2.5 Zones on open deck, spaces other than cargo spaces.**

**2.2.5.1** In zones on open decks or non-enclosed spaces on open deck, with 3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange, cargo valves or entrances and ventilation openings to cargo pump rooms and cargo compressor rooms; in zones on the open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck and up to a height of 2,4 m above the deck; in zones within 2,4 m of the outer surface of a cargo containment system where such surface is exposed to the weather the following may be installed:

- .1 certified safe-type equipment;
- .2 through runs of cables.

**2.2.5.2** In enclosed or semi-enclosed spaces in which pipes containing cargoes are located and in compartments for cargo hoses the following may be installed:

- .1 lighting fittings with pressurized enclosures, or of the flameproof type.

The lighting system is to be divided and supplied by at least two feeders. All switches and protective devices are to interrupt all poles or phases and be located in gas-safe spaces as specified in Section 9;

- .2 through runs of cables.

**2.2.5.3** In enclosed or semi-enclosed spaces having a direct opening into any gas-dangerous space or zone there are to be installed electrical installations complying with the requirements for the installations located in these gas-dangerous spaces or zones.

**2.2.5.4** Electrical equipment within spaces protected by air locks is to be of the certified safe type unless arranged to be de-energized upon loss of overpressure in the space.

**2.2.5.5** Classification and dimensions of dangerous spaces for ships with regasification unit shall be determined in compliance with IEC 60092-502. However, in any case they shall be no less than given in 2.2.5.1.

### **3 EARTHING**

**3.1** Metal means of protecting cables installed on the upper deck and passing through dangerous areas against mechanical damage, are to be earthed at least at both ends of each protective means (housing, steel pipe, armoured braiding).

**3.2** Metal cargo tanks and piping separated from the hull structure by heat insulation and the connections of pipes and hoses having gaskets are to be earthed.

### **4 SOURCES OF ELECTRICAL POWER**

**4.1** Generators with their driving engines which utilize gas fuel are not to be considered as main sources of electrical power.

## **5 POWER SUPPLY OF ESSENTIAL SERVICES**

**5.1** The following consumers are to be supplied from the main switchboard busbars:

- .1** switchboards of cargo pumps;
- .2** switchboard of gas re-liquefaction compressors;
- .3** inert gas plant switchboard;
- .4** switchboard of alarm to indicate presence of gas in spaces;
- .5** switchboard of cargo storage and transfer system alarm and control;
- .6** switchboard of fans for pressurization of air locks and safe-type electrical equipment enclosures;
- .7** switchboards of buster pumps and gas-air blowers.

**5.2** Consumers listed in 5.1.4 and 5.1.5 may be supplied from the integrated control console of cargo containment system. It is recommended to supply these consumers through the emergency switchboard.

**5.3** Power supply of electric (electronic) automation systems is to comply with the requirements of Part XV "Automation" of the Rules for the Classification, except for power supply of automation devices for starting the emergency diesel generator which is to meet the requirements of 4.4.2, Part XI "Electrical Equipment" of the Rules for the Classification.

## **6 DISTRIBUTION OF ELECTRICAL POWER FROM EMERGENCY SOURCES**

**6.1** The following consumers are to be supplied through separate feeders from the emergency switchboard busbars:

- .1** switchboard of alarm to indicate presence of cargo vapours in spaces;
- .2** switchboard of fans for pressurization of air locks and safe-type electrical equipment enclosures;
- .3** air lock door position alarm switchboard;
- .4** all necessary components of at least one heating system for hull structures (refer to 19.2.6.2, Part IV "Cargo Containment");
- .5** electric heaters of the heating system for hull structures, if such heaters are required by 19.2.6.3, Part IV "Cargo Containment".

## **7 LOCATION OF SWITCHBOARDS AND SWITCHGEAR**

**7.1** Switchboards and switchgear are not to be located in the air lock spaces.

## **8 ELECTRIC DRIVES FOR SHIPBOARD MECHANISMS AND EQUIPMENT**

### **8.1 General.**

**8.1.1** Electric motors of non-safe type installed in spaces, the access to which is provided through air locks are to be fitted with interlocking devices that will switch off the power upon loss of overpressure in the air lock and prevent switching-on until the pressure is restored to its original value.

### **8.2 Electric drives of pumps.**

**8.2.1** The electric drives of cargo pumps, buster pumps and compressors are to be provided with switches for automatic disconnection thereof upon closure of quick-closing valves in the piping.

**8.2.2** The electric drives of submerged cargo pumps are to be provided with switches for automatic disconnection thereof in the event of low liquid level in a cargo tank as specified in 2.2.2.

**8.2.3** The electric motors of cargo pumps, buster pumps, gas-air blowers and compressors of the gas re-liquefaction plant are to be located in spaces separated from the associated dangerous spaces by a gastight bulkhead and are to be connected with their mechanisms through flexible couplings. Where the motor shafts pass through the bulkhead, gastight glands are to be fitted.

**8.3 Electric drives of fans.**

**8.3.1** The electric drives of ventilation fans for pressurizing of air locks, spaces protected by air locks and safe-type electrical equipment enclosures are not to be used for other purposes.

**8.3.2** The electric motors of fans are not to be located in the ventilation ducts of the exhaust and supply ventilation of dangerous spaces.

**8.3.3** Opening of the doors and switching-on of the electrical equipment installed in these spaces are to be interlocked with the fan drive in such a way that the entrance into the spaces and switching-on of the electrical equipment is only possible after starting of the fans and their operation during a time period necessary to provide 3 to 4 air changes in this space.

## **9 LIGHTING**

**9.1** The lighting system of dangerous spaces and areas is to be divided between at least two branch circuits and is to be supplied from different switchboards.

**9.2** Switches and protective devices of the lighting system of dangerous spaces and areas are to be located outside the dangerous spaces and areas and interrupt all phases.

**9.3** Lighting fittings of dangerous spaces and areas are to have pressurized enclosures (*Exp*) or are to be of flameproof type (*Exd*).

## **10 ALARM SYSTEM**

**10.1** A permanently installed cargo vapour detection alarm system is to be provided for spaces and areas listed in 6.3, Part VIII "Instrumentation and Automation Systems".

**10.2** Visible and audible alarms to indicate a dangerous cargo vapour concentration are to be located in the gas-sampling locations (spaces), on the navigation bridge and in the cargo control room.

In the locations where permanent watch is kept, common alarms are to be activated when the gas concentration exceeds the prescribed limit.

**10.3** Two independent power supply sources are to be provided for the alarm system. The main source is to be the ship's mains, the standby source — an accumulator battery.

**10.4** If the alarm system is supplied from the ship's mains through the emergency generator switchboard, the capacity of the accumulator battery is to be sufficient for continuous supplying this system during 30 min. In all other cases, this time is to be not less than specified in 9.3.1, Part XI "Electrical Equipment" of the Rules for the Classification.

**10.5** Alarms to indicate automatic shutdown of submerged cargo pumps, closure of quick-closing valves, presence of water in the interbarrier spaces, cargo leakage into the cargo heater condensate and operation of the inert gas generation plant are to be located in the cargo control room.

The alarm to indicate presence of water in the interbarrier space is to be duplicated in the wheelhouse.

**10.6** When gas is utilized as fuel, the alarms to indicate the pressure drop in the fuel piping or the failure of gas fuel supply to the machinery of the engine room are to be located in the main machinery control room.

**10.7** The alarms to indicate the loss of overpressure in the air locks and in the safe-type electrical equipment with pressurized enclosures (*Exp*), are to be located in the main machinery control room and in the locations where permanent watch is kept.

## **11 CONSTRUCTION OF ELECTRICAL EQUIPMENT**

**11.1** Parts of electrical equipment and cables which are in permanent contact with the liquefied gases or their vapours, or come into short-time contact with them are to be manufactured of materials resistant to chemical attack.

**11.2** Cables intended for the installation in dangerous spaces and areas are to withstand, without damage, the temperatures encountered in the said spaces over a long period of time, as well as elongation equal to 1/700 of the length of the metal structures on which they are installed.

## **PART VIII. INSTRUMENTATION AND AUTOMATION SYSTEMS**

### **1 GENERAL**

**1.1** Each cargo tank is to be provided with means for indicating level, pressure and temperature of the cargo.

Pressure gauges and temperature indicating devices are to be installed in the liquid and vapour piping systems, in cargo refrigerating installations and in the inert gas system according to the requirements of the present Part.

**1.2** Where a secondary barrier is required, permanently installed instrumentation is to be provided to detect liquid cargo leaks when the primary barrier fails to be liquid-tight or when liquid cargo is in contact with the secondary barrier. This instrumentation may consist of appropriate gas detecting devices according to Section 6.

However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

**1.3** If the loading or unloading of the ship is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank are to be concentrated in one control position.

**1.4** Instruments are to be tested in the working conditions and recalibrated at regular intervals. Test procedure for instruments and the intervals between recalibration are to be approved by the Register.

### **2 LEVEL INDICATORS FOR CARGO TANKS**

**2.1** Each cargo tank shall be fitted with one or several liquid level gauging devices arranged to ensure that a level reading is always obtainable whenever the cargo tank is operational. The devices shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.

Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank. In order to assess whether or not only one level gauge is acceptable, phrase "can be maintained" means that any part of the level gauge other than passive parts can be overhauled while the cargo tank is in service. For this purpose, passive parts are those parts assumed not subject to failures under normal service conditions.

**2.2** Cargo tank liquid level gauges may be of the following types subject to any special requirements for particular cargoes shown in column 8 of the Table of Technical Requirements (Appendix 1):

**.1** indirect devices, which determine the amount of cargo by means such as weighing or pipe flow meters;

**.2** closed devices, which do not penetrate the cargo tank, such as devices using radioisotopes or ultrasonic devices;

**.3** closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as pneumatic devices, float type systems, electronic probes, magnetic probes.

If a closed gauging device is not mounted directly on the tank it is to be provided with a shut-off valve located as close as possible to the tank;

**.4** restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere. When not in use, the devices are to be kept completely closed. The design and installation of these devices is to ensure that no dangerous escape of cargo can take place when opening the device. The area of the openings being uncovered during gauging is not to exceed 7 mm<sup>2</sup>.

**2.3** Sighting ports with a suitable protective cover and situated above the liquid level with an internal scale may be allowed by the Register as a secondary means of gauging for cargo tanks having a design vapour pressure not higher than 70 kPa.

**2.4** Tubular glasses are not to be used as level indicators.

Gauge glasses of the robust type as fitted on high-pressure boilers and fitted with excess flow valves may be allowed by the Register for deck tanks.

### **3 LIQUID LEVEL ALARMS**

**3.1** Except as provided in 3.2, each cargo 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, to the cargo control room and to the wheelhouse. On receiving such warning, the operator on board who is in charge of the loading operations is to inform the personnel of the shore terminal about interruption of the loading.

Besides, another device operating independently of the high liquid level alarm is to automatically shut down shipboard pumps and/or automatically actuate an emergency shutdown valve in a manner which will both avoid excessive liquid pressure in the cargo main and prevent the tank from becoming liquid full. The emergency shutdown valve is to comply with the requirements of 3.2, Part VI "Systems and Piping". Information on the availability of such device is to be submitted to the Administration of the shore terminal before the loading.

**3.2** Except as provided in Part X "Special Requirements", a high liquid level alarm and automatic shutoff of cargo tank filling are not required when the cargo tank:

is a pressure tank with a volume not more than 200 m<sup>3</sup>; or

is designed to withstand the maximum possible pressure during the loading operation and such pressure is below that of the start-to-discharge pressure of the cargo tank relief valve.

### **4 PRESSURE GAUGES**

**4.1** The vapour space of each cargo tank is to be provided with a pressure gauge which is to incorporate an indicator in the cargo control room. In addition, a high-pressure alarm and, if vacuum protection is fitted, a low-pressure alarm, is to be provided on the navigation bridge. Maximum and minimum allowable pressures are to be marked on the indicators.

**4.2** Each cargo pump discharge line and each liquid and vapour cargo manifold are to be provided with a pressure gauge.

**4.3** Local-reading manifold pressure gauges are to be provided to indicate the pressure between stop valves and hose connections to the shore.

**4.4** Hold spaces and interbarrier spaces without open connection to the atmosphere are to be provided with pressure gauges.

**4.5** The pressure gauge blowing-off pipes are to be carried to a safe place.



## **5 TEMPERATURE INDICATING DEVICES**

**5.1** Each cargo tank is to be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level.

The temperature indicating devices are to be marked to show the lowest temperature at which the cargo tank may be used.

**5.2** When a cargo is carried in cargo tanks with a secondary barrier at a temperature lower than  $-55\text{ }^{\circ}\text{C}$ , temperature indicating devices are to be provided within the insulation or on the hull structure adjacent to the cargo tanks.

The devices are to give readings at regular intervals and, where applicable, audible warning of temperatures approaching the lowest for which the hull steel is suitable.

**5.3** If cargo is carried at temperatures lower than  $-55\text{ }^{\circ}\text{C}$ , the cargo tank boundaries, if appropriate for the design of the cargo tank, are to be fitted with temperature indicating devices as follows:

- .1** a sufficient number of devices to establish that an unsatisfactory temperature gradient does not occur;
- .2** on one tank a number of devices in excess of those required in 5.3.1 in order to monitor the initial cool down procedure. These devices may be either temporary or permanent.

**5.4** The number and position of temperature indicating devices shall be sufficient for making substantiated decisions on the state of the cargo and its containment systems.

## **6 GAS DETECTORS**

**6.1** Gas detectors approved by the Register and suitable for the gases to be carried are to be provided in accordance with column 7 of the Table of Technical Requirements (Appendix 1).

**6.2** The positions of fixed sampling heads are to be determined with due regard to the density of the vapours of the products intended to be carried and the dilution from compartment purging or ventilation.

**6.3** A permanently installed gas detection system is to be provided for:

- .1** cargo pump rooms;
- .2** cargo compressor rooms;
- .3** motor rooms for cargo pumps;
- .4** cargo control rooms unless considered as gas-safe spaces;
- .5** other enclosed spaces in the cargo area where vapour may accumulate including hold spaces and interbarrier spaces for independent tanks other than type C;
- .6** ventilation hoods and gas ducts where required by Section 11, Part VI "Systems and Piping";
- .7** air locks.

Audible and visual alarms from the gas detection system are to be located in the cargo control room, on the navigation bridge and at the gas detector readout location.

**6.4** Gas detectors may be located in the cargo control room, on the navigation bridge or at other suitable locations.

When gas detectors are located in a gas-safe space the following conditions are to be met:

- .1** gas-sampling lines are to be fitted with flame arresters. Sampled gas is to be discharged to the atmosphere via a special discharge pipe situated in a safe location;
- .2** penetrations of the gas-sampling lines through gastight bulkheads are to be of approved type and have the same fire integrity as the bulkhead concerned;
- .3** each gas-sampling line is to be fitted with a manually operated shut-off isolating valve installed on the gastight bulkhead on the gas-safe side;
- .4** gas detection equipment is to be located in a special tight steel cabinet. One measuring point is to be within the cabinet. When the dangerous gas concentration within the cabinet reaches 30 % of the lower flammable limit, gas supply to the gas detector is to be automatically cut off;

**.5** gas-sampling lines are generally not be led through the spaces outside the gas-dangerous zone. If the cabinet for gas detection cannot be located on a gastight bulkhead, gas-sampling lines are to be as short as possible, made of steel or equivalent material and have no detachable connections, except for connections with the gas detection cabinet and isolating valves on the gastight bulkhead.

**6.5** Gas detectors are to be capable of sampling and analysing for each sampling head location sequentially at intervals not exceeding 30 min, except that in the case of gas detection for the ventilation hoods and gas ducts referred to in 6.3.6 sampling is to be continuous.

Common sampling lines to gas detectors are not be fitted.

**6.6** Pipes running from sampling heads are not to be led through gas-safe spaces except as permitted by 6.4.

**6.7** For the spaces listed in 5.3, alarms are to be activated for flammable products when the vapour concentration reaches 30 % of the lower flammable limit.

**6.8** In case of flammable products, where cargo containment systems other than independent tanks are used, hold spaces and interbarrier spaces are to be provided with a permanently installed gas detection system capable of measuring gas concentrations of 0 to 100 % by volume.

**6.9** In case of toxic gases, hold spaces and interbarrier spaces are to be provided with a permanently installed piping system for obtaining gas samples from the spaces and areas. Gas from these spaces is to be sampled and analysed from each sampling head location by means of fixed or portable equipment at intervals not exceeding 4 h and in any event before personnel enter the space and at 30-min intervals when they remain therein.

**6.10** In case of toxic or both toxic and flammable products, the Register may authorize the use of portable equipment for detection of toxic gases in the spaces listed in 6.3 as an alternative to a permanently installed gas detection system, if such equipment is used before personnel enter these spaces and at 30-min intervals while they remain therein.

The portable equipment is not required for the products, for which column 10 of the Table of Technical Requirements (Appendix 1) refers to Section 11, Part X "Special Requirements".

**6.11** Gas detectors are to be so designed that they may readily be tested. Testing and calibration are to be carried out at regular intervals. Permanent connections are to be fitted for testing and calibration by metrological services.

**6.12** Every ship is to be provided with at least two sets of portable gas detectors approved by the Register and suitable for the products to be carried.

**6.13** A suitable instrument for the measurement of oxygen levels in inert atmosphere is to be provided.

**6.14** Gas detectors intended for detecting gas in accommodation spaces, service spaces and control stations are to have a measuring range within the limits of the maximum allowable concentrations of gases for the carriage of which the ship is intended.

**6.15** In addition to the requirements specified in 6.3, on board the ships fitted with the regasification unit the gas detection system be extended with a sufficient number of gas detectors of continuous monitoring type provided for:

- regasification units;
- metering units;
- suction drum;
- export manifold;
- storage tanks for flammable fluids or gases, if fitted on the weather deck;
- ventilation inlets to gas safe spaces;
- odorization units;
- turret compartment.

## **7 AUTOMATION SYSTEMS**

**7.1** The requirements of this Section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by the LG Rules.

**7.2** Automation systems shall be designed, installed and tested in compliance with the LG Rules and IEC 60092-504:2001 "Electrical installations in ships — Special features — Control and instrumentation".

**7.3** Hardware shall be applied suitable for use in the marine environment.

**7.4** Software shall be designed and documented for ease of use, including testing, operation and maintenance.

**7.5** The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.

**7.6** Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.

**7.7** Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the automation systems that are required to provide specified functions, including connected devices and power supplies.

**7.8** Automation systems shall be arranged such that the software configuration and parameters are protected against unauthorized or unintended change.

**7.9** A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained on board.

**7.10** Processes for the development and maintenance of integrated systems shall be in compliance with ISO/IEC 15288:2008 "Systems and software engineering – System life cycle processes", and ISO 17894:2005 "Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications". These processes shall include appropriate risk identification and management.

### **7.11 System integration.**

**7.11.1** Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the Administration, both in normal operation and under fault conditions. Functions shall be designed to fail-safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by relevant parties.

**7.11.2** Functional requirements of each component subsystem shall be clearly defined to ensure that the integrated system meets the functional and specified safety requirements and takes account of any limitations of the equipment under control.

**7.11.3** Key hazards of the integrated system shall be identified using appropriate risk-based techniques. The designer shall develop and submit for approval the procedure for failure mode and effects analysis (FMEA) (in compliance with IEC 60812:2006).

**7.11.4** The integrated system shall have a suitable means of reversionary control.

**7.11.5** Failure of one part (module, hardware or subsystem unit) of the integrated system shall not affect the functionality of other parts, except for those functions directly dependent on the defective part. The total communication failure between parts of the integrated system shall not affect the parts functionality in independent mode.

**7.11.6** Operation with an integrated system shall be at least as effective as it would be with individual stand-alone equipment or systems.

**7.11.7** The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated. The failures may be realistically simulated to demonstrate a failure detection and the system response.

## **PART IX. MATERIALS AND WELDING**

### **1 GENERAL**

**1.1** The requirements of the present Part apply to plates, sections, pipes, forgings and castings used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping, secondary barriers, as well as to welded joints of the above products.

The requirements also cover hull structural steel plates and sections according to 3.2, Part XIII "Materials" of the Rules for the Classification, which are used for manufacture of structures subjected to low temperatures, but of other than parts of the secondary barrier.

The requirements for rolled materials, forgings and castings are given in Tables 2.1-1 to 2.1-5, and for welded structures, in Section 3 of the present Part.

**1.2** The manufacture, testing, survey and documentation are to meet the requirements of Part XIII "Materials" of the Rules for the Classification, the approved standards and the requirements of the present Part.

**1.3** Unless otherwise required by the Register, the impact tests in accordance with 2.2.3, Part XIII "Materials" of the Rules for the Classification on the specimens according to Fig. 2.2.3.1-2 and Table 2.2.3.1-2 of the above Part are to be carried out; in addition, the standards for the minimum impact energy *KV* are established according to 2.2.3.1 and Table 2.2.3.1-4 of the above Part.

For base metal, the largest size specimens possible for the material thickness shall be machined. The requirements for tests of metal thickness less than 5 mm shall comply with the national and/or international standards. In the case where the material thickness is 40 mm or below, the test specimens shall be cut with their edge within 2 mm from the "as rolled" surface with their longitudinal axes parallel to the final direction of rolling of the material, and the surfaces shall be machined. For steel thickness over 40 mm the specimens shall be cut with their longitudinal axes 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. V-notches shall be made perpendicular to the surface.

On agreement with the Register, in addition to or instead of impact tests other tests may be carried out to determine brittle fracture resistance (crack resistance), e.g. the drop weight test.

In case of unsatisfactory results for bending impact test the re-testing shall be conducted in compliance with 1.3.2, Part XIII "Materials" of the Rules for the Classification.

**1.4** The ultimate strength, yield stress and elongation of a specific material are to be given in the documentation to be approved by the Register.

**1.5** The bend test may be omitted for a base material, but is required during testing of welded joints.

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.

**1.6** The Register may accept materials with alternative chemical composition and/or mechanical properties.

**1.7** Where post-weld heat treatment is specified, the properties of the base material are to be determined in the heat-treated condition in accordance with Tables 2.1-1 to 2.1-5, and the weld properties are to be determined in the heat-treated condition according to the requirements of Section 3.

In cases where a post-weld heat treatment is applied, the test requirements may be modified on agreement with the Register.

**1.8** Steels with A, B, D, E, AH, DH, EH and FH grades shall comply with 3.2 and 3.5 of Part XIII "Materials" of the Rules for the Classification accordingly.

**1.9** During the initial survey and in case of discrepancies between the results of the acceptance tests and the requirements specified in an appropriate section of the Rules, macrosection, microsection observations and hardness tests shall be performed in accordance with 3.2 of Part XIII "Materials" of the Rules for the Classification.

**1.10** Aluminium alloys applied in the cargo containment structures of gas carriers shall comply with the requirements for aluminium alloys of Section 5, Part XIII "Materials" of the Rules for the Classification, as well as of Section 10, Part XIII "Materials" of the Rules for the Classification.

## **2 MATERIAL REQUIREMENTS**

**2.1** The requirements for materials of construction are shown in the tables as follows:

Table 2.1-1: plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0 °C;

Table 2.1-2: plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0 °C and down to –55 °C;

Table 2.1-3: plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55 °C and down to –165 °C;

Table 2.1-4: pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0 °C and down to –165 °C;

Table 2.1-5: plates and sections for hull structures subjected to lowered cargo temperatures.

**2.2** Castings and forgings intended for cargo and process piping for design temperature above 0 °C shall comply with the requirements of the recognized national and/or international standards.

## **3 WELDING AND NON-DESTRUCTIVE TESTING**

### **3.1 General.**

**3.1.1** These requirements shall apply to primary and secondary barriers, including the inner hull where this forms the secondary barrier.

The requirements of this Section are those generally employed for carbon, carbon-manganese, nickel alloy and austenitic steels, and may form the basis for acceptance testing of other material.

On agreement with the Register, impact testing of stainless steel and aluminium alloy weldments may be omitted.

The Register may demand other types of testing for any material.

### **3.2 Welding consumables.**

**3.2.1** Welding consumables intended for welding of cargo tanks are to be recognized by the Register, have the relevant Certificate of Approval for Welding Consumables and be in compliance with the standards and/or specifications agreed with the Register.

Deposited weld metal tests and butt weld tests are to be conducted for all welding consumables, unless otherwise stated.

The results obtained from tensile and Charpy V-notch impact tests are to meet the Register requirements.

The chemical composition of the deposited weld metal is subject to agreement with the Register.

### **3.3 Welding procedure tests for cargo tanks, process pressure vessels and secondary barriers.**

#### **3.3.1 Number and location of test assemblies.**

**3.3.1.1** Welding procedure tests are to be conducted for all butt welds of:

each base material;

each type of consumable and welding process;

each welding position.

Butt test assemblies in steel plates are to be so prepared that the rolling direction is parallel to the direction of welding.

The range of thicknesses qualified by each welding procedure test is established on agreement with the Register.

Radiographic or ultrasonic testing may be performed at the discretion of the manufacturer or the Register.

Table 2.1-1

Plates, pipes (seamless and welded <sup>1</sup> ), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0 °C							
<b>Chemical composition</b> Carbon-manganese steel. Fully killed. Fine grain steel. Chemical composition of the steel shall comply with the requirements of national/international standard or manufacture's specification approved by the Register							
<b>Heat treatment</b> Normalized, or quenched and tempered <sup>2</sup>							
<b>Tensile and Charpy V-notch impact tests</b> Plates Each piece shall be tested Sections and forgings Each batch shall be tested Tensile properties Specified minimum yield stress not exceeding 410 MPa <sup>3</sup>							
<b>Charpy V-notch impact test</b> Plates Transverse test pieces Minimum average impact energy value ( <i>KV</i> ) 27 J Sections and forgings Longitudinal test pieces Minimum average impact energy value ( <i>KV</i> ) 41 J							
<b>Impact test temperature</b> <table> <tr> <td>Thickness <i>S</i>, in mm</td><td>Test temperature, in °C</td></tr> <tr> <td><math>S \leq 20</math></td><td>0</td></tr> <tr> <td><math>20 &lt; S \leq 40</math></td><td>–20</td></tr> </table>		Thickness <i>S</i> , in mm	Test temperature, in °C	$S \leq 20$	0	$20 < S \leq 40$	–20
Thickness <i>S</i> , in mm	Test temperature, in °C						
$S \leq 20$	0						
$20 < S \leq 40$	–20						
<sup>1</sup> For seamless pipes and fittings in compliance with the requirements of the Rules for the Classification and Construction. Charpy V-notch impact tests are not required for pipes. <sup>2</sup> A controlled rolling procedure or TMCP may be used as an alternative provided the properties specified in the Rules are guaranteed by the manufacturer. <sup>3</sup> Hardness of the weld and heat affected zones shall meet the approved international and/national standards and norms.							

Table 2.1-2

Plates, sections and forgings <sup>1</sup> for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0 °C and down to –55 °C. Maximum thickness <sup>2</sup> 25 mm							
<b>Chemical composition</b> Carbon-manganese steel. Fully killed. Aluminium treated fine grain steel. Chemical composition (ladle analysis):							
C	Mn		Si		S		P
0,16 max <sup>3</sup>	0,70 — 1,60		0,10 — 0,50		0,025 max		0,025 max
Alloys and grain refining elements may be generally in accordance with the following:							
Ni	Cr	Mo	Cu	Nb	V	Al	
0,80 max	0,25 max	0,08 max	0,35 max	0,05 max	0,10 max	0,02 min	
<b>Heat treatment</b> Normalized or quenched and tempered <sup>4</sup>							
<b>Charpy V-notch impact test</b> Plates Each piece shall be tested Sections and forgings Each batch shall be tested Tensile properties Specified minimum yield stress not exceeding 410 MPa <sup>5</sup>							
<b>Impact tests</b> Plates Transverse test pieces. Minimum average impact energy value ( <i>KV</i> ) 27 J Sections and forgings <sup>1</sup> Longitudinal test pieces. Minimum average impact energy value ( <i>KV</i> ) 41 J							
<b>Impact test temperature</b> 5 °C below design temperature or –20 °C, whichever is lower							
<sup>1</sup> Chemical composition of forgings shall comply with the specification approved by the Register. <sup>2</sup> For material thickness more than 25 mm thick, Charpy V-notch impact tests shall be conducted as follows: Material thickness <i>S</i> , in mm                      Test temperature, in °C 25 < <i>S</i> ≤ 30                      5 °C below design temperature or –20 °C, whichever is lower 30 < <i>S</i> ≤ 35                      15 °C below design temperature or –20 °C, whichever is lower 35 < <i>S</i> ≤ 40                      20 °C below design temperature The Charpy V-notch impact energy value shall be in accordance with the table for applicable type of test specimen. Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5 °C below design temperature or –20 °C, whichever is lower. For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness. <sup>3</sup> Carbon content may be increased to 0,18 % maximum provided the design temperature is not lower than –40 °C. <sup>4</sup> A controlled rolling procedure or TMCP may be used as an alternative to normalizing or quenching and tempering, provided the properties specified in the Rules are guaranteed by the manufacturer. For materials exceeding 25 mm in thickness for which the test temperature is –60 °C or lower, the application of specially treated steel or steels in accordance with Table 2.1-3 shall be stipulated by the Rules. <sup>5</sup> Hardness of the weld and heat affected zones shall meet the approved international and/national standards and norms.							

Table 2.1-3

Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures <sup>1</sup> below –55 °C and down to –165 °C. Maximum thickness <sup>2</sup> 25 mm		
Minimum design temperature, in °C	Chemical composition <sup>3</sup> and heat treatment	Charpy V-notch impact test temperature, °C
–60	1,5 % nickel steel N or N+T or Q+T or TMCP	–65
–65	2,25 % nickel steel N or N+T or Q+T or TMCP <sup>4</sup>	–70
–90	3,5 % nickel steel N or N+T or Q+T or TMCP <sup>4</sup>	–95
–105	5 % nickel steel N or N+T or Q+T or TMCP <sup>4,5</sup>	–110
–165	9 % nickel steel N+N+T or Q+T	–196
–165	Austenitic steels such types* 304, 304L, 316, 316L, 321 and 347 Solution treated	–196
–165	Aluminium alloys type* 5083, 1550, 1565ch Annealed	Not required
–165	Austenitic Fe-Ni alloy (36 % Ni)	Not required
<b>Tensile and Charpy V-notch impact test</b>		
Plates	Each piece shall be tested	
Sections and forgings	Each batch shall be tested	
<b>Charpy V-notch impact test</b>		
Plates	Transverse specimens Minimum average energy value (KV) 27J	
Sections and forgings	Longitudinal test pieces Minimum average energy value (KV) 41J	
<sup>1</sup> The requirements for materials use at design temperatures below –165 °C shall comply with the values specified in the national/international standards.		
<sup>2</sup> For steel 1,5 %; 2,25 %; 3,5 % and 5 % Ni, with thickness greater than 25 mm, the test temperature shall be corrected as follows:		
Thickness S (in mm)	Test temperature, in °C	
25 < S ≤ 30	10 °C below design temperature	
30 < S ≤ 35	15 °C below design temperature	
35 < S ≤ 40	20 °C below design temperature	
The Charpy V-notch impact energy value shall be in accordance with the table for the applicable type of test specimen.		
<sup>3</sup> The chemical composition limits shall comply with the approved specification.		
<sup>4</sup> A lower minimum design temperature for quenched and tempered steels may be permitted.		
<sup>5</sup> A specially heat treated, e.g. 5 % nickel steel, for example triple heat treated 5 % nickel steel may be used down to –165 °C, provided that the Charpy V-notch impact tests are carried out at –196 °C.		
*In compliance with the international and national standards.		

Procedure tests for consumables intended for fillet welding are to be performed in accordance with the requirements of Part XIV "Welding" of the Rules for the Classification; in such cases welding consumables are to ensure the required impact energy value in the impact test.

### 3.3.2 Test scope.

**3.3.2.1** The selected welding procedures for cargo tanks and process pressure vessels specified in this para shall meet the requirements of 1.2.

The following welding procedure tests are specified for each test assembly:

- .1** cross-weld tensile tests;
- .2** longitudinal all-weld tensile testing shall comply with the requirements of national or international standard;
- .3** transverse bend tests. However, longitudinal bend tests may be required in lieu of transverse bend tests where base material and bend metal have different strength levels;
- .4** one set of three Charpy V-notch type specimens for the impact test is to be selected from the following locations (Fig. 3.3.2.1.3):
  - centerline of the weld (1);
  - fusion line (FL) (2);
  - 1 mm from the FL (3);

Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0 °C and down to – 165 8C. Maximum thickness 25 mm.			
Minimum design temperature, in °C	Chemical composition <sup>1</sup> and heat treatment	Impact tes	
		Test temperature, in °C	Minimum average impact energy value ( <i>KV</i> ), in J
– 55	Carbon-manganese steel. Fully killed. Fine grain steel. N or treated.	— <sup>2</sup>	27
– 65	2,25 % nickel steel N or N + T or Q + T <sup>3</sup>	– 70	34
– 90	3,5 % nickel steel N, N + T, Q + T <sup>3</sup>	– 95	34
– 165	Steel of 9 % Ni <sup>4</sup> N, N + T, Q + T	– 196	41
– 165	Austenitic steel types* 304, 304L, 316, 316L, 321 и 347 Solution treated <sup>8</sup>	– 196	41
	Aluminium alloys type* 5083 Annealed		Not required
<b>Tensile and charpy V-notch impact test</b> Each batch shall be tested			
<b>Charpy V-notch impact test</b> Longitudinal specimens			
<sup>1</sup> The chemical composition limits shall comply with the specification approved by the Register. <sup>2</sup> The test temperature should shall be 5°C below the design temperature or –20°C whichever is lower. <sup>3</sup> A lower minimum design temperature may be permitted for quenched and tempered materials. <sup>4</sup> This chemical composition is not suitable for castings.			
*In compliance with the international and national standards.			

Plates and sections for hull structures receiving lower cargo temperature							
Minimum design temperature of hull structure, in °C	Maximum thickness, in mm, for steel grades						
	A	B	D	E	A32 A36 A40	D32 D36 D40	E32 E36 E40
0 and above <sup>1</sup> —5 and above <sup>2</sup>	In accordance with 1.4, Part II "Hull" of the Rules for the Classification						
down to —5	15	25	30	50	25	45	50
down to —10	*	20	25	50	20	40	50
down to —20	*	*	20	50	*	30	50
down to —30	*	*	*	40	*	20	40
Below —30	In accordance with Table 2.1-2 except that the thickness limitation given in Footnote 2 to the Table does not apply						
<sup>1</sup> For cases specified in 19.2.3, Part IV "Cargo Containment".							
<sup>2</sup> For cases specified in 19.2.2, Part IV "Cargo Containment".							
* This steel grade is not to be used.							



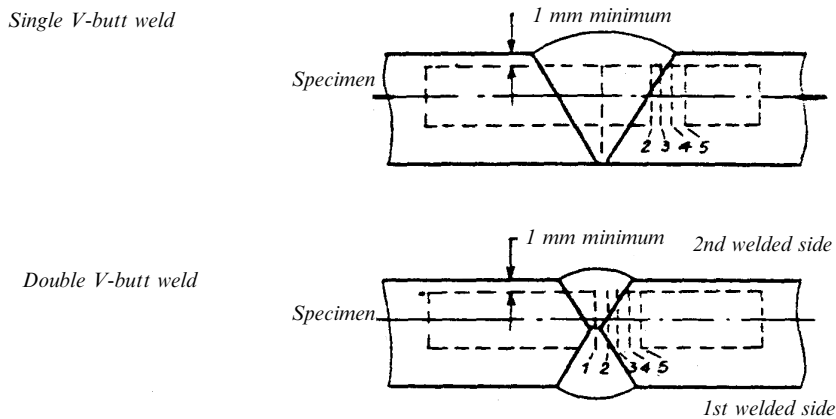


Fig. 3.3.2.1.3 Orientation of weld test specimen

3 mm from the FL (4);

5 mm from the FL (5);

.5 macrosection analysis. The Register may also require the microsection analysis and hardness determination.

### 3.4 Tests.

#### 3.4.1 Tensile tests.

**3.4.1.1** Tensile strength in testing of welded joints shall not be less than required for the base metal. The tensile strength of the weld metal below the tensile strength of the parent metal is allowed on a special agreement with the Register, unless in the tensile test of the transverse weld specimen, the tensile strength is less than that specified for the weld metal. In every case, the position of fracture is to be reported for information.

#### 3.4.2 Bend tests.

**3.4.2.1** No fracture is acceptable after 180° bend over a former diameter of  $4t$  where  $t$  is the thickness of the test pieces.

#### 3.4.3 Charpy V-notch impact tests.

**3.4.3.1** Charpy tests are to be conducted at the temperature prescribed for the base materials being joined. In impact tests of the weld metal, the impact energy value is to be at least 27 J.

The requirements in testing of subsize specimens and the permissible impact energy value for a single specimen are to be in accordance with 2.2.3.1 and Table 2.2.3.1-4, Part XIII "Materials" of the Rules for the Classification.

The results of fusion line and heat affected zone impact tests are to meet the requirements for the base material for longitudinal or transverse specimens whichever is applicable, and for subsize specimens, similarly to specified in 1.3.

### 3.5 Fillet Welding Procedure Tests.

**3.5.1** The requirements for fillet welding procedure tests are given in Section 6, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships. In such cases, welding consumables shall be selected which exhibit Charpy V-notch impact properties complying with the Register requirements.

### 3.6 Welding Procedure Tests for Secondary Barriers.

**3.6.1** Welding procedure tests for secondary barriers shall be carried out.

### 3.7 Welding procedure tests for piping welded joints.

**3.7.1** Welding procedure tests for piping welded joints similar to the tests specified in 3.2 are to be conducted.

The test requirements are to be in accordance with 3.4 unless provided otherwise.

### **3.8 Production weld tests.**

**3.8.1** For all cargo tanks and process pressure vessels except integral and membrane tanks, production weld tests are generally to be performed for approximately each 50 m of butt-welded joints and are to be representative of each welding position.

For secondary barriers, the same type production tests are to be performed, but their scope may be reduced on agreement with the Register.

Tests, other than those specified in 3.8.2 to 3.8.4, may be required for cargo tanks or secondary barriers at the discretion of the Register.

Test requirements shall comply with 3.4. The test program shall be based on the technical documentation of the manufacture and shall be approved by the Register.

**3.8.2** The production tests for types A and B independent tanks and semi-membrane tanks are to include the following tests.

**3.8.2.1** Bend tests and impacts test where required for procedure tests. One set of three Charpy V-notch specimens is to be tested for each 50 m of weld. The impact tests are to be made with specimens having the notch located either in the centre of the weld or 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.

**3.8.3** In addition to the tests for type C independent tanks and process pressure vessels, transverse weld tensile tests are also to be performed.

**3.8.4** Production weld tests for integral and membrane cargo tanks shall be performed in accordance with 3.3.2.

### **3.9 Non-destructive testing.**

**3.9.1** For type A independent tanks and semi-membrane tanks where the design temperature is  $-20^{\circ}\text{C}$  or less, and for type B independent tanks regardless of temperature, 100 % of full penetration butt welds of the shell plating of cargo tanks are to be subjected to radiographic testing.

**3.9.1.1** Where the design temperature is higher than  $-20^{\circ}\text{C}$ , all full penetration butt welds in way of intersections and at least 10 % of the remaining full penetration welds of tank structures are to be subjected to radiographic testing.

**3.9.1.2** In each case the welds of other cargo tank structures including the welding of stiffeners and other fittings and attachments are to be subjected to non-destructive testing on agreement with the Register.

**3.9.2** For type C independent tanks and process pressure vessels, the extent of non-destructive testing shall be total or partial according to RS recognized manufacture quality standards, but the controls to be carried out shall not be less than those specified in 3.9.2.1 and 3.9.2.2.

**3.9.2.1** Total non-destructive testing referred to in 23.2.1, Part IV "Cargo Containment":

**.1** radiographic testing:

all butt welds over their full length;

**.2** 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 3.9.7 may be accepted as a partial substitute for the radiographic testing. In addition, total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc may be required.

**3.9.2.2** Partial non-destructive testing referred to in 23.2.1, Part IV "Cargo Containment"

**.1** radiographic testing:

all butt-welded crossing joints and at least 10 % of the full length of butt welds at selected positions uniformly distributed;

**.2** non-destructive testing for surface crack detection:

reinforcement rings around holes, nozzles, etc., over their full length;

**.3** ultrasonic testing:

the controls to be carried out shall be approved by the Register.

**3.9.3** Non-destructive testing of welded joints of the inner hull or the independent tank structures supporting internal insulation tanks is to take into account the design criteria specified in 23.2.1, Part IV "Cargo Containment". The non-destructive testing scope and methods are to be agreed with the Register.

**3.9.4** For integral and membrane cargo tanks, special weld non-destructive testing methods and acceptance criteria are subject to agreement with the Register.

**3.9.5** Non-destructive testing of piping is to be carried out in accordance with the requirements of Part VI "Systems and Piping".

**3.9.6** The welds of secondary barrier structures are subject to radiographic testing in the scope agreed with the Register.

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 subject to radiographic testing.

**3.9.7** All test procedures of non-destructive testing and acceptance standards shall be in accordance with Section 3, Part XIV "Welding" of the Rules for the Classification.

A non-destructive ultrasonic testing procedure in lieu of radiographic testing may be conducted. However, supplementary radiographic testing at selected locations shall be carried out to verify the results.

The manufacturer shall submit to the Register for the review a program of non-destructive testing and the documentation of the firm quality assurance system to ensure the required extent of non-destructive testing of the firm's products.

The relevant records of the testing results shall be submitted to the Register.

## **PART X. SPECIAL REQUIREMENTS**

### **1 GENERAL**

**1.1** The requirements of the present Part apply where reference is made in column 10 of the Table of Technical Requirements (Appendix 1) and supplement the general requirements of the LG Rules.

### **2 PERSONNEL PROTECTION**

**2.1** Suitable respiratory and eye protection for emergency escape purposes shall be provided for every person on board, subject to the following:

- .1** filter-type respiratory protection is unacceptable;
- .2** self-contained breathing apparatus shall have at least a duration of service of 15 min; and
- .3** emergency escape respiratory protection shall not be used for firefighting or cargo-handling purposes and shall be marked to that effect.

**2.2** One or more suitably marked decontamination showers and eyewash stations shall be available on deck, taking into account the size and layout of the ship. The showers and eyewashes shall be operable in all ambient conditions.

### **3 MATERIALS OF CONSTRUCTION**

**3.1** Mercury, copper, zinc, copper-bearing alloys are not to be used as materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

**3.2** Copper, silver, mercury, magnesium and other acetylide-forming metals are not to be used as materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

**3.3** Aluminium and aluminium-bearing alloys are not to be used as materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

**3.4** Copper, copper alloys, zinc or galvanized steel are not to be used as materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

**3.5** Aluminium, copper and alloys of either are not to be used as materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

**3.6** Copper and copper-bearing alloys with greater than 1 % copper are not to be used as materials of construction for cargo tanks, and associated pipelines, valves, fittings and other items of equipment which may be exposed to liquid cargo or its vapour.

#### **4 INDEPENDENT TANKS**

**4.1** Products are to be carried in independent tanks only.

**4.2** Products are to be carried in type C independent tanks and the requirements of 4.1.3, Part VI "Systems and Piping" are to be complied with.

The design pressure of the cargo tank is to take into account the pressure of any medium used to separate air from cargo, and/or vapour discharge unloading pressure.

#### **5 REFRIGERATION SYSTEMS**

**5.1** Only the indirect system described in 4.2.2.2, Part VI "Systems and Piping" is to be used.

**5.2** For a ship engaged in the carriage of products which readily form dangerous peroxides, recondensed cargo is not to be allowed to form stagnant pockets of inhibited liquid. This may be achieved either by:

using the indirect system described in 4.2.2.2, Part VI "Systems and Piping" with the condenser inside the cargo tank; or

using the direct system or combined system described in 4.2.2.1 and 4.2.2.3, Part VI "Systems and Piping", or the indirect system described in 4.2.2.2 of the same Part with the condenser outside the cargo tank, and designing the condensate system to avoid any places in which liquid could collect and be retained. Where this is impossible inhibited liquid is to be added into such places.

**5.3** If the ship is to carry consecutively products as specified in 5.2 with a ballast passage between, all uninhibited liquid is to be removed prior to the ballast voyage.

If a second cargo is to be carried between such consecutive cargoes, the reliquefaction system is to be thoroughly drained and purged before loading the second cargo. Purging is to be carried out using either inert gas or vapour from the second cargo, if compatible.

Practical steps are to be taken to ensure that polymers or peroxides do not accumulate in the ship's cargo system.

#### **6 DECK CARGO PIPING**

**6.1** 100 % radiography of all butt-welded joints in cargo piping exceeding 75 mm in diameter is required.

#### **7 BOW OR STERN LOADING AND UNLOADING ARRANGEMENTS**

**7.1** In **type 1G** gas carriers, bow or stern loading and unloading lines are not to be laid in accommodation spaces, service spaces and control stations.

In **type 2G** and **2PG** gas carriers, bow or stern loading and unloading lines may be used for the transfer of dangerous products unless specifically approved by the Register.

## **8 EXCLUSION OF AIR FROM VAPOUR SPACES**

**8.1** Air is to be removed from the cargo tanks and associated piping before loading and then subsequently excluded by:

introducing inert gas to maintain a positive pressure. Storage or production capacity of inert gas is to be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of inert gas is at no time to be greater than 0,2 % by volume; or

control of cargo temperatures such that a positive pressure is maintained at all times.

## **9 MOISTURE CONTROL**

**9.1** For gases, which are non-flammable and may become corrosive or react dangerously with water, moisture control is to be provided to ensure that cargo tanks are dry before loading and during discharge, dry air or cargo vapour is introduced to prevent negative pressures. Dry air is air which has a dewpoint of  $-45\text{ }^{\circ}\text{C}$  or below at atmospheric pressure.

## **10 INHIBITION**

**10.1** Care is to be taken to ensure that the cargo is sufficiently inhibited to prevent polymerization at all times during the voyage.

## **11 PERMANENTLY INSTALLED TOXIC GAS DETECTORS**

**11.1** Gas sampling lines are not to be led into or through gas-safe spaces. Alarm is to be activated when the vapour concentration reaches the threshold limiting value.

**11.2** The alternative of using portable equipment in accordance with 6.9, Part VIII "Instrumentation and Automation Systems" is not permitted.

## **12 ETHYLENE OXIDE**

**12.1** Cargo piping system and vent piping system are to be completely separated from all other piping systems.

**12.2** Hold spaces are to be inerted in accordance with 8.1.

**12.3** Vapour spaces of cargo tanks are to be filled with nitrogen in accordance with 8.1 at a pressure equal to the difference between the cargo vapour pressure at  $30\text{ }^{\circ}\text{C}$  and the set pressure of the relief valve.

**12.4** Ethylene oxide is to be discharged only by deepwell pumps or inert gas displacement.

**12.5** Ethylene oxide is to be carried refrigerated only and maintained at temperatures of less than  $30\text{ }^{\circ}\text{C}$ .

**12.6** Pressure relief valves of the cargo tanks are to be set at a pressure of not less than 0,55 MPa.

**12.7** A jettisoning arrangement is to be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

**12.8** Aluminium and aluminium alloys, copper and copper alloys, silver and silver alloys, magnesium and magnesium alloys, stainless steel, cast iron, mercury, asbestos are not to be used as materials of construction.

### 13 METHYL ACETYLENE-PROPADIENE MIXTURES

**13.1** Methyl acetylene-propadiene mixtures are to be suitably stabilized for transport. Additionally, upper and lower limits of temperature and pressure during the refrigeration are to be specified for the mixtures.

**13.2** A ship carrying methyl acetylene-propadiene mixtures is to have an indirect refrigeration system as required in 4.2.2.2, Part VI "Systems and Piping".

Alternatively, a ship may utilize direct-expansion refrigeration system subject to pressure and temperature limitations depending on the composition of mixtures. In this case, for the example compositions given in column 1 of the Table of Technical Requirements (Appendix 1), the following features are to be provided:

**.1** a vapour compressor that does not raise the temperature and pressure of the vapour above 60 °C and 1,75 MPa, and that does not allow vapour to stagnate in the compressor while it continues to run;

**.2** discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor is to have:

**.2.1** two temperature-actuated shutdown switches set to operate at 60 °C or less;

**.2.2** a pressure-actuated shutdown switch set to operate at 1,75 MPa or less;

**.2.3** a safety relief valve set to relieve at 1,8 MPa or less and which vents to the vent system described in Section 5, Part VI "Systems and Piping";

**.3** an alarm that gives an audible and visual warning to the cargo control room and to the navigation bridge when a high-pressure switch, or a high-temperature switch operates.

**13.3** The piping system, including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixtures is to be either independent or separate from piping and refrigeration systems for other tanks by the removal of spool pieces, valves or other pipe sections and the installation of blank flanges at these locations.

This segregation applies to all liquid and vapour vent pipes and any other possible connections, such as common inert gas supply lines.

### 14 NITROGEN

**14.1** Materials of construction and insulation are to be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system.

Ventilation is to be provided in such areas where condensation may occur to avoid the stratification of oxygen-enriched atmosphere.

### 15 CHLORINE

#### **15.1 Cargo tanks.**

**15.1.1** The capacity of each tank is not to exceed 600 m<sup>3</sup> and the total capacity of all cargo tanks is not to exceed 1200 m<sup>3</sup>.

**15.1.2** The tank design vapour pressure is not to be less than 1,35 MPa (see also 4.1.3, Part VI "Systems and Piping" and 4.2 of this Part).

**15.1.3** Parts of tanks protruding above the upper deck are to be provided with protection against thermal radiation taking into account total engulfment by fire.

**15.1.4** Each tank is to be provided with two pressure relief valves. A bursting disc is to be installed between the tank and the pressure relief valves. The rupture pressure of the bursting disc is to be 0,1 MPa lower than the opening pressure of the pressure relief valve, which is to be set at the design vapour

pressure of the tank but not less than 1,35 MPa. The space between the bursting disc and the relief valve is to be connected through an excess flow valve to a pressure gauge and a gas detection system.

Provision is to be made to keep this space at or near the atmospheric pressure during normal operation.

**15.1.5** Outlets from pressure relief valves are to be arranged in such a way as to minimize the hazards on board the ship as well as to the environment.

Leakage from the relief valves is to be led through the absorption plant to reduce the gas concentration as far as possible.

The relief valve exhaust line is to be arranged at the forward end of the ship to discharge outboard at deck level with an arrangement to select either port or starboard side, with a mechanical interlock to ensure that one line is always open.

**15.1.6** The Register may require that chlorine is carried in refrigerated state at a specified or maximum pressure.

## **15.2 Cargo piping systems.**

**15.2.1** Cargo discharge is to be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas or fully submerged pumps. The pressure in the vapour space of the tank during discharging is not to exceed 1,05 MPa.

Cargo discharge compressors on board ships are not permitted.

**15.2.2** The design pressure of the cargo piping system is not to be less than 2,1 MPa. The internal diameter of the cargo pipes is not to exceed 100 mm.

Only pipe bends are to be accepted for compensation of pipeline thermal movement. The use of flanged joints is to be restricted to a minimum, and when used the flanges are to be of the welding neck type with tongue and groove.

**15.2.3** Relief valves of the cargo piping system are to discharge to the absorption plant and in this case the back pressure in the vent lines as specified in 3.6.2, Part VI "Systems and Piping" is to be taken into account.

## **15.3 Materials.**

**15.3.1** The cargo tanks and cargo piping systems are to be made of steel suitable for the cargo and for a temperature of  $-40^{\circ}\text{C}$ , even if a higher transport temperature is intended to be used.

**15.3.2** The tanks are to be thermally stress relieved. Mechanical stress relief is not to be accepted as an equivalent.

## **15.4 Instrumentation.**

**15.4.1** The ship is to be provided with a chlorine absorbing plant with connections to the cargo piping system and the cargo tanks. The absorbing plant is to be capable of neutralizing at least 2 % of the total cargo capacity at a reasonable absorption rate.

**15.4.2** During the gas-freeing of cargo tanks, vapours are not to be discharged to the atmosphere.

**15.4.3** A gas detection system is to be provided capable of monitoring chlorine concentrations of at least 1 ppm by volume. Suction points are to be located:

- near the bottom of the hold spaces;

- in the pipes from the safety relief valves;

- at the outlet of the gas absorbing plant;

- at the inlet to the ventilation systems for the accommodation, service and machinery spaces and control stations;

- on deck at the forward end, in the middle and at the after end of the cargo area (required to be used only during cargo handling and gas-freeing operations).

Audible and visual alarms activated when chlorine vapours reach concentration of more than 5 ppm are to be provided in spaces listed in 6.3, Part VIII "Instrumentation and Automation Systems", as well as in the wheelhouse.

**15.4.4** Each cargo tank is to be fitted with high-pressure alarm giving an audible alarm at a pressure equal to 1,05 MPa.



### **15.5 Personnel protection.**

**15.5.1** In addition to the requirements of Section 2 the following requirements are to be met.

**15.5.1.1** The collective protection space required by 2.4 is to be easily and quickly accessible from the open deck and from accommodation spaces and is to be capable of being rapidly closed gas-tight. Access to this space from the deck and from the accommodation spaces is to be by means of an air lock. The space is to be so designed as to accommodate the entire crew of the ship and be provided with a source of uncontaminated air for a period of not less than 4 h. One of the decontaminated showers required by 2.2 is to be located near the air lock to this space.

**15.5.1.2** A compressor and the necessary equipment for filling the air bottles are to be provided.

**15.5.1.3** One set of oxygen therapy equipment is to be carried in the space referred to in 15.5.1.1.

### **15.6 Filling limits for cargo tanks.**

**15.6.1** The requirements of 3.7.4.2, Part VI "Systems and Piping" do not apply when it is intended to carry chlorine.

**15.6.2** The chlorine content of the gas in the vapour space of the cargo tank after loading is to be greater than 80 % by volume.

## **16 VINYL CHLORIDE**

**16.1** Sufficient inhibitor is to be added into the product to prevent its polymerization during the voyage.

**16.2** In cases where no or insufficient inhibitor has been added, any inert gas used for the purposes of Section 8 is to contain not more oxygen than 0,1 %. Before loading is started, inert gas samples from the tanks and piping are to be analysed.

**16.3** When vinyl chloride is carried, a positive pressure is to always be maintained in the tanks, also during ballast voyages between successive carriages.

## **17 DIETHYL ETHER AND VINYL ETHYL ETHER**

**17.1** In case of unloading by means of pumps, the cargo is to be discharged only by hydraulically operated submerged pumps. These pumps are to be of a type designed to avoid liquid pressure against the shaft gland.

**17.2** Inert gas displacement may be used for discharging cargo from type C independent tanks provided the cargo system is designed for the expected pressure.

## **18 PROPYLENE OXIDE AND MIXTURES OF ETHYLENE OXIDE-PROPYLENE OXIDE WITH ETHYLENE OXIDE CONTENT OF NOT MORE THAN 30 % BY WEIGHT**

**18.1** Products transported under the requirements of the present Section are to be acetylene-free.

**18.2** Tanks for the carriage of these products are to be of steel or stainless steel construction.

**18.3** All valves, flanges, fittings and accessory equipment are to be of a type suitable for use with these products and are to be constructed of steel or stainless steel or other material acceptable to the Register. The chemical composition of all materials to be used is to be submitted to the Register for approval before manufacture.

Discs or disc faces, seats and other wearing parts of valves are to be made of stainless steel containing not less than 11 % chromium.

**18.4** Gaskets are to be constructed of materials which do not react with, dissolve in, or lower the autoignition temperature of these products and which are fire-resistant and possess adequate mechanical behaviour.

The surface presented to the cargo is to be polytetrafluoroethylene (PTFE) or materials giving a similar degree of safety by their inertness.

Spirally-wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted by the Register.

**18.5** Insulation and packing if used are to be of material which does not react with, dissolve in, or lower the autoignition temperature of these products.

**18.6** The following materials are generally found unsatisfactory for gaskets, packing and similar uses in containment systems for these products and are to undergo testing before being approved by the Register:

neoprene or natural rubber if it comes into contact with the products;

asbestos or binders used with asbestos;

materials containing oxides of magnesium, such as mineral wools.

**18.7** Filling and discharge piping is to be extended to within 100 mm of the bottom of the tank or any sump.

**18.8** The products are to be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product is to be independent of all other containment systems.

"Independent" means that a piping or venting system is in no way connected to another system and there are no means available for the potential connection to other systems.

**18.9** During discharging operations, the pressure in the cargo tank is to be maintained above 7 kPa.

**18.10** The cargo is to be discharged only by hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump is to be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

**18.11** Tanks carrying these products are to be vented independently of tanks carrying other products.

Facilities are to be provided for sampling the tank contents without opening the tank to atmosphere.

**18.12** Cargo hoses used for transfer of these products are to be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".

**18.13** Hold spaces are to be monitored for these products. Hold spaces surrounding type A and B independent tanks are also to be inerted and monitored for oxygen. The oxygen content of these spaces is to be maintained below 2 %. Portable sampling equipment is permitted.

**18.14** Prior to disconnecting shore-lines, the pressure in liquid and vapour lines is to be relieved through suitable valves installed in the loading header. Liquid and vapour from these lines are not to be discharged to atmosphere.

**18.15** Cargo tanks are to be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.

**18.16** Tanks for the carriage of propylene oxide with a design vapour pressure of less than 60 kPa and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than 120 kPa are to have a cooling system to maintain the cargo below the reference temperature.

**18.17** For type C independent tanks, the pressure relief valve settings are not to be less than 21 kPa and not greater than 0,7 MPa for the carriage of propylene oxide and not greater than 0,53 MPa for the carriage of ethylene oxide-propylene oxide mixtures.

**18.18** The piping system for tanks to be loaded with these products is to be completely separate from piping systems for all other tanks, including empty tanks, and from all cargo compressors.

If the piping system for the tanks to be loaded with these products is not independent as defined in 18.8 the required piping separation is to be accomplished by the removal of spool pieces, valves, or other pipe sections and the installation of blank flanges at these locations.

The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections such as common inert gas supply lines.

**18.19** The products may be transported only in accordance with cargo-handling plans approved by the Register.

Each intended loading arrangement is to be shown on a separate cargo-handling plan.

Cargo-handling plans are to show the entire cargo piping system and the locations for installation of blank flanges needed to meet the above piping separation requirements.

A copy of each approved cargo-handling plan is to be kept on board the ship.

The Certificate is to include reference to the approved cargo-handling plans.

**18.20** Before each initial loading of these products, a certificate verifying that the required piping separation has been achieved is to be obtained from a competent authority representative and carried on board the ship.

Each connection between a blank flange and pipeline flange is to be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

**18.21** The maximum allowable tank filling limits for each tank are to be indicated for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Register. A copy of the list is to be permanently kept on board by the master.

**18.22** The cargo is to be carried under suitable protective padding of nitrogen gas. Nitrogen of commercially pure quality (99,9 % by volume) is to be used for padding.

An automatic nitrogen make-up system is to be installed to prevent the tank pressure falling below 7 kPa in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system.

Sufficient nitrogen is to be available on board to satisfy the demand of the automatic pressure control.

A battery of nitrogen bottles connected to the cargo tanks through a pressure reduction valve satisfies the intention of the expression "automatic" in this context.

**18.23** The cargo tank vapour space is to be tested prior to and after loading to ensure that the oxygen content is 2 % by volume or less.

**18.24** A water spray system of such capacity and arrangement as to blanket effectively the area surrounding the exposed deck cargo piping and the tank domes is to be provided in areas where loading and unloading operations are performed.

The arrangement of piping and nozzles is to be such as to give a uniform distribution rate of 10 l/min per m<sup>2</sup>.

The water spray system is to be capable of both local and remote manual operation and the arrangement is to ensure that any spilled cargo is washed away. Additionally, a water hose with pressure to the nozzle, when ambient temperatures permit, is to be connected ready for immediate use during loading and unloading operations.

## 19 AMMONIA

**19.1** Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon-manganese steel or nickel steel. To minimize the risk of this occurring, measures detailed in 19.2 to 19.8 are to be taken, as appropriate.

**19.2** 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 MPa and with an actual yield strength not exceeding 440 MPa. One of the following constructional or operational measures is also to be taken.

**19.2.1** Material with a specified minimum tensile strength not exceeding 410 MPa is to be used.

**19.2.2** Cargo tanks, piping, etc., are to be post-weld stress relief heat treated.

**19.2.3** Carriage temperature is to be maintained at a temperature close to the product's boiling point of  $-33\text{ }^{\circ}\text{C}$  but in no case at a temperature above  $-20\text{ }^{\circ}\text{C}$ .

**19.2.4** The ammonia is to contain not less than 0,1 % w/w water.

**19.3** If carbon-manganese steels with higher yield properties are used other than those specified in 19.2, the cargo tanks, piping, etc., are to be given a post-weld stress relief heat treatment.

**19.4** Process pressure vessels and piping of the condensate part of the refrigeration system are to be given a post-weld stress relief heat treatment when made of materials mentioned in 19.1.

**19.5** The required tensile and yield properties of the welding consumables are to exceed those of any tank or piping material to be welded.

**19.6** Nickel steel containing more than 5 % nickel and carbon-manganese steel not complying with the requirements of 19.2 and 19.3 are particularly susceptible to stress corrosion cracking and are not to be used in containment and piping systems for the processing and carriage of the ammonia.

**19.7** Nickel steel containing not more than 5 % nickel may be used provided the carriage temperature complies with the requirements specified in 19.2.3.

**19.8** In order to minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2,5 ppm w/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 in Table 19.8.

Table 19.8

Carriage temperature, in °C	Oxygen content, in % by volume
–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 percentage for intermediate temperatures may be obtained by linear interpolation.	

## 20 VAPOUR RETURN PIPELINES

**20.1** Pipelines are to be provided to return vapour to the shore installation during loading operations.

## 21 TOXIC PRODUCTS

**21.1** Toxic products are to have individual piping systems.

## 22 FLAME SCREENS ON VENT OUTLETS

**22.1** Cargo vent outlets are to be provided with permanent or readily renewable and effective flame screens or safety heads preventing the passage of sparks and flame into the cargo tanks, when carrying a cargo specified in this Part. In the design of flame screens and vent heads the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions is to be provided.

Ordinary protection screens are to be fitted after removal of the flame screens.

## 23 MAXIMUM ALLOWABLE QUANTITY OF CARGO PER TANK

**23.1** When carrying a cargo specified in this Part, the quantity of the cargo is not to exceed 3000 m<sup>3</sup> in any one tank.

## **24 INCOMPATIBLE CARGOES**

**24.1** Incompatible cargoes are substances which react dangerously one with another and form new dangerous substances.

**24.2** During simultaneous transportation of two or more cargoes, which can react dangerously one with another, separate gas piping and gas discharge from cargo systems having no permanent connection with each other and both complying with operational safety criteria specified in 24.3 shall be provided. In case of simultaneous transportation of two or more cargoes not reacting with one another but whose vapour properties require isolated systems, the said systems may be separated by shutoff valves.

**24.3** Operational safety of the system and its auxiliary devices shall be such that:

**.1** in case of a single failure of mechanical elements or non-static regulation system elements, pressure and temperature in the cargo tank remain in the design values range not impacting other essential functions;

**.2** no redundancy of piping systems is needed;

**.3** heat exchangers necessary for maintaining pressure and temperature in the design values range have a redundant heat exchanger except for the cases when their heat power output exceeds that necessary for pressure regulation by more than 25 %, and they can be repaired onboard the ship without external resources. If an additional pressure and temperature regulation device independent of the heat exchanger is provided onboard, the redundant heat exchanger is not necessary; and

**.4** for any substance used in the cargo heating or cooling system, means for the detection of toxic or flammable vapour leakage into the safe space or overboard in accordance with the requirements of Section 6, Part VIII "Instrumentation and Automation Systems". Any outlet of such leakage detection device shall be in the safe zone and be fitted with a flame arrester.

## **25 CARRIAGE OF CARGOES IDENTIFIED (\*) IN THE TABLE OF TECHNICAL REQUIREMENTS (APPENDIX 1)**

**25.1** In case where cargoes identified (\*) in the Table of Technical Requirements (refer to Appendix 1) are carried, the ship is also to meet the applicable requirements of the Rules for the Classification and Construction of Chemical Tankers.

## **26 MIXED C4 CARGOES**

**26.1** Cargoes that may be carried individually under the requirements of the IGC Code, notably butane, butylenes and butadiene, may be carried as mixtures subject to the provisions of this section. These cargoes may variously be referred to as "Crude C4", "Crude butadiene", "Crude steam-cracked C4", "Spent steam-cracked C4", "C4 stream", "C4 raffinate", or may be shipped under a different description. In all cases, the material safety data sheets (MSDS) shall be consulted as the butadiene content of the mixture is of prime concern as it is potentially toxic and reactive. While it is recognized that butadiene has a relatively low vapour pressure, if such mixtures contain butadiene they shall be regarded as toxic and the appropriate precautions applied.

**26.2** If the mixed C4 cargo shipped under the terms of this section contains more than 50 % (mole) of butadiene, the inhibitor precautions in 10.1 shall apply.

**26.3** Unless specific data on liquid expansion coefficients is given for the specific mixture loaded, the filling limit restrictions of 3.7, Part VI "Systems and Piping" shall be calculated as if the cargo contained 100 % concentration of the component with the highest expansion ratio.

## **27 CARBON DIOXIDE: HIGH PURITY**

**27.1** Uncontrolled pressure loss from the cargo can cause "sublimation" and the cargo will change from the liquid to the solid state. The precise "triple point" temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this section shall be set to at least 0,05 MPa above the triple point for the specific cargo being carried. The "triple point" for pure carbon dioxide occurs at 0,5 MPa gauge and  $-54,4^{\circ}\text{C}$ .

**27.2** There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with 3.16, Part VI "Systems and Piping", fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of 3.16.7.2 do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of 5.8 do not apply.

**27.3** Cargo tanks shall be continuously monitored for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0,05 MPa of the "triple point" for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown (ESD) system may be used for this purpose.

**27.4** All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in 27.1.

**27.5** Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of Section 6, Part VIII "Instrumentation and Automation Systems", and hold spaces shall be monitored permanently even if the ship has type C cargo containment.

## **28 CARBON DIOXIDE: RECLAIMED QUALITY**

**28.1** The requirements of Section 28 apply to this cargo. the materials of construction used in the cargo system shall also take account of the possibility of corrosion, in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc., which can cause acidic corrosion or other problems.

## **TABLE OF TECHNICAL REQUIREMENTS**

### **Explanatory notes to the Table of Technical Requirements**

1. Product names (column 1) are listed in alphabetic order of their Latin names.
2. Chemical formula (column 2) is given for information only.
3. Density (column 3) is given for information only and is to be refined according to the shipper's data.
4. Ship type (column 4) according to the definition in Part I "Classification".
5. Definition of the type C independent tank (column 5) is given in Section 23, Part IV "Cargo Containment".
6. Requirements for control of vapour space within cargo tanks (column 6) are given in Part V "Fire Protection":
  - Inert = inert gas;
  - Dry = dry air.
7. Vapour detection system (column 7):
  - F = flammable vapour detection;
  - T = toxic vapour detection;
  - O = oxygen detection (oxygen analyzer);
  - F+T = flammable and toxic vapor detection.
8. Gauge type (column 8):
  - R = restricted type;
  - C = closed type;
  - I = indirect type (see 2.2, Part VIII "Instrumentation and Automation Systems").
9. MFAG (Medical First Aid Guide (MFAG) of the International Maritime Organization (IMO)) numbers (column 9) are provided for information on the emergency procedures in accidents associated with the products covered by the LG Rules requirements.

Where any of the products listed are carried at the low temperature from which frostbite may occur, MFAG No. 620 is also applicable.
10. Special requirements (column 10), see chapters and sections of Part X "Special Requirements".
11. Products marked "\*" are also covered by the requirements of the Rules for the Classification and Construction of Chemical Tankers.

Product name	Chemical formula	Density (kg/m <sup>3</sup> ) at temperature in brackets	Ship type	Type C independent tank required	System for control of vapour space within cargo tanks	Cargo vapour detection system	Gauge type	MFAG table No.	Special requirements
Acetaldehyde	CH <sub>3</sub> CHO	780 (20,8°C)	2G/2PG	—	Inert	F+T	C	300	2.2, 2.3, 5.1, Section 7, Section 8
Ammonia Anhydrous	NH <sub>3</sub>	771 (−33,4°C)	2G/2PG	—	—	T	C	725	2.1, 2.2, 2.3, 3.1, Section 7
Butadiene	CH <sub>2</sub> CHCHCH <sub>2</sub>	646 (0°C)	2G/2PG	—	—	F+T	R	310	3.2, 5.2, Section 8, Section 10
Butane	C <sub>4</sub> H <sub>10</sub>	600 (0°C)	2G/2PG	—	—	F	R	310	
Butane/Propane mixture (LPG)			2G/2PG	—	—	F	R	310	
Butylenes	CH <sub>3</sub> CH <sub>2</sub> CHCH <sub>2</sub>	670 (0°C)	2G/2PG	—	—	F	R	310	
Chlorine	Cl <sub>2</sub>	1560 (−34°C)	1G	Yes	Dry	T	I	740	Section 2, 4.2, 5.1, Section 6, Section 7, Section 9, Section 11, Section 15
Diethyl Ether*	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O	640 (34,6°C)	2G/2PG	—	Inert	F+T	C	330	2.1, 2.2, 3.6, 4.1, 8.1, Section 17, Section 22, Section 23
Dimethylamine	(CH <sub>3</sub> ) <sub>2</sub> NH	680 (0°C)	2G/2PG	—	—	F+T	C	320	2.1, 2.2, 2.3, 3.1, Section 7
Ethane	CH <sub>3</sub> CH <sub>3</sub>	550 (−88°C)	2G	—	—	F	R	310	
Ethyle Chloride	CH <sub>3</sub> CH <sub>2</sub> Cl	921 (0°C)	2G/2PG	—	—	F+T	R	340	Section 7
Ethylene	C <sub>2</sub> H <sub>4</sub>	560 (−104°C)	2G	—	—	F	R	310	
Ethylene Oxide	CH <sub>2</sub> CH <sub>2</sub> O	882 (10°C)	1G	Yes	Inert	F+T	C	365	2.1, 2.2, 2.3, 2.5, 3.2, 4.2, Section 6, Section 7, Section 8, Section 12
Ethylene Oxide/Propylene Oxide mixture with Ethylene Oxide content of not more than 30 % by weight*			2G/2PG	—	Inert	F+T	C	365	2.2, 4.1, 5.1, 8.1, Section 18, Section 22, Section 23
Isoprene*	CH <sub>2</sub> CHC(CH <sub>3</sub> )CH <sub>2</sub>	680 (34°C)	2G/2PG	—	—	F	R	310	2.2, Section 10, Section 19, Section 22
Isopropylamine*	(CH <sub>3</sub> ) <sub>2</sub> CHNH <sub>2</sub>	710 (34°C)	2G/2PG	—	—	F+T	C	320	2.1, 2.2, 3.4, Section 7, Section 20, Section 21, Section 22, Section 23
Methane (LNG)	CH <sub>4</sub>	420 (−164°C)	2G	—	—	F	C	620	
Methylacetylene/Propadiene mixture			2G/2PG	—	—	F	R	310	Section 13
Methyl Bromide	CH <sub>3</sub> Br	1730 (0°C)	1G	Yes	—	F+T	C	345	Section 2, 3.3, Section 4, 5.1, Section 6, Section 11
Methyl Chloride	CH <sub>3</sub> Cl	920	2G/2PG	—	—	F+T	C	340	3.3, Section 7
Monoethylamine* (Ethylamine)	C <sub>2</sub> H <sub>5</sub> NH <sub>2</sub>	706 (0°C)	2G/2PG	—	—	F+T	C	320	2.1, 2.2, 2.3, 3.1, 4.1, Section 7, Section 20, Section 21, Section 22, Section 23
Nitrogen	N <sub>2</sub>	808 (−196°C)	3G	—	—	O	C	620	Section 14



*Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk*

*Appendix-129*

Product name	Chemical formula	Density (kg/m <sup>3</sup> ) at temperature in brackets	Ship type	Type C independent tank required	System for control of vapour space within cargo tanks	Cargo vapour detection system	Gauge type	MFAG table No.	Special requirements
Pentanes (all isomers)*	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	626 (0 °C)	2G/2PG	—	—	F	R	310	2.3, 8.1, Section 22
Pentene (all isomers)*			2G/2PG	—	—	F	R	310	2.3, 8.1, Section 22
Propane	CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub>	590 (-42,3 °C)	2G/2PG	—	—	F	R	310	
Propylene	CH <sub>3</sub> CHCH <sub>2</sub>	860	2G/2PG	—	—	F	R	310	
Propylene Oxide*	CH <sub>3</sub> CHOCH <sub>2</sub>	830	2G/2PG	—	Inert	F+T	C	365	2.2, 4.1, 5.1, Section 7, 8.1, Section 18, Section 20, Section 22, Section 23
Refrigerant gases: Dichlorodifluoromethane	CCl <sub>2</sub> F <sub>2</sub>	1490 (-30 °C)	3G	—	—	—	R	350	
Dichloromonofluoromethane	CHFC1 <sub>2</sub>	1480 (8,9 °C)							
Dichlorotetrafluoroethane	C <sub>2</sub> F <sub>4</sub> Cl <sub>2</sub>	1510 (3,8 °C)							
Monochlorodifluoromethane	CHClF <sub>2</sub>	1420 (-42 °C)							
Monochlorotetrafluoroethane	C <sub>2</sub> HF <sub>4</sub> Cl								
Monochlorotrifluoromethane	CF <sub>3</sub> Cl	1520 (-81,4 °C)							
Sulphur Dioxide	SO <sub>2</sub>	1460 (-10°C)	1G	Yes	Dry	T	C	635	Section 2, Section 4, 5.1, Section 6, Section 7, Section 9, Section 11
Vinyl Chloride*	CH <sub>2</sub> CHCl	970 (-13,9 °C)	2G/2PG	—	—	F+T	C	340	
Vinyl Ethyl Ether	CH <sub>2</sub> CHOC <sub>2</sub> H <sub>5</sub>	755	2G/2PG	—	Inert	F+T	C	330	2.1, 2.2, 3.2, 4.1, Section 7, 8.1, Section 10, Section 17, Section 19, Section 21, Section 22
Vinylidene Chloride*	C <sub>2</sub> H <sub>2</sub> CCl <sub>2</sub>	1250	2G/2PG	—	Inert	F+T	R	340	2.1, 2.2, 3.2, 4.1, Section 7, 8.1, Section 10, Section 17, Section 19, Section 21, Section 22 2.1, 2.2, 3.5, Section 7, Section 10, Section 19, Section 21, Section 22
Dimethyl Ether	C <sub>2</sub> H <sub>6</sub> O	1,716	2G/2PG	—	—	B+T	C	—	
Mixed cargoes C4			2G/2PG			B+T	3. K	—	2.1, 3.2, 5.2, 5.3, 8.1, Section 26
Carbon dioxide (high purity)	CO <sub>2</sub>	771	3G			O	3		Section 27
Carbon dioxide (high purity)	CO <sub>2</sub>	771	3G			O	3		Section 28

*APPENDIX 2*

**INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS  
CARRYING LIQUEFIED GASES IN BULK**

Refer to Chapter 18 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).

*APPENDIX 3*

**NON-METALLIC MATERIALS**

Refer to Appendix 4 to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).

*APPENDIX 4*

**STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN  
OF CARGO CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION**

Refer to Appendix 5 to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).

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**для перевозки сжиженных газов наливом**

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**Rules for the Classification and Construction**  
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