



RULES FOR  
CLASSIFICATION OF  
**SHIPS**

NEWBUILDINGS

SPECIAL SERVICE AND TYPE  
ADDITIONAL CLASS

PART 5 CHAPTER 5

# LIQUEFIED GAS CARRIERS

JANUARY 2008

*This booklet includes the relevant amendments and corrections  
shown in the July 2009 version of Pt.0 Ch.1 Sec.3.*

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# CHANGES IN THE RULES

## General

The present edition of the rules includes additions and amendments approved by the Board as of December 2007 and June 2008, and supersedes the January 2007 edition of the same chapter, including later amendments.

The rule changes come into force as indicated below.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of minor amendments and corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

## Main changes adopted July 2009

### Coming into force 1 January 2010

- **Sec.5 Scantlings and Testing of Cargo Tanks**
  - The requirement in item H401 has been aligned with the requirement for tank type A (Sec.5 E). Allowable stress in static condition has been changed from 60% of (static + dynamic) to 70%.

## Significant editorial changes adopted January 2009

### Taking effect immediately

- **Sec.5 Scantlings and Testing of Cargo Tanks**
  - A new Guidance note has been inserted in C105 regarding methods for strength analysis of hull structures in liquefied gas carriers with membrane tanks (a reference to Classification Note 31.9).

## Main changes adopted July 2008

### Coming into force 1 January 2009

- **Sec.16 Gas Operated Propulsion Machinery**
  - The Guidance note in item C103 has been amended to cover extended testing.

## Main changes adopted January 2008

### Coming into force 1 January 2008

- **Sec.2 Materials and Hull Strength**
  - Table E1 has been modified to align with current material requirements.
- **Sec.5 Scantlings and Testing of Cargo Tanks**
  - The last row of Table M1 has been modified to clarify the NDT of the second barrier. The table has been aligned with the ICG extent of testing, otherwise reference has been made to Pt.2 Ch.3 Sec.7.
- **Sec.6 Piping Systems in Cargo Area**
  - Item H301 has been amended by increasing the diameter, when DNV product certificate is required for valves, from 75 mm to 100 mm.
- **Sec.14 Test after Installation**
  - A new sub-section element A200 "Secondary Barrier testing requirements" has been added to align with IACS UI GC 12.

### Coming into force 1 July 2008

- **Sec.1 General Requirements**
  - In new item A203, the class notations for regasification (**REGAS-1** and **REGAS-2**) have been added
  - In new item A204, the requirements covering the class notation **STL** concerning submerged turret loading for gas carriers have been added.
- **Sec.16 Gas Operated Propulsion Machinery**
  - In item D101, the class notation **GAS FUELLED** has been made mandatory for gas carriers with gas fuelled engine installations, other than steam driven LNG carriers.
- **Sec.18 Inert Gas Plants**
  - In item A201, cross references to Pt.5 Ch.3 have been clarified. Further, a Guidance note with reference to relevant IACS unified requirements UI F20 has been inserted.
- **App.A List of Cargoes (Tanker for Liquefied Gas)**
  - Carbon Dioxide and Dimethyl Ether have been added to the list of cargoes.

## Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made to the existing rule text.

Comments to the rules may be sent by e-mail to [rules@dnv.com](mailto:rules@dnv.com)

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Computer Typesetting (Adobe FrameMaker) by Det Norske Veritas

Printed in Norway

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## SECTION 1 GENERAL REQUIREMENTS

### A. Classification

#### A 100 Application

**101** The rules in this chapter apply to ships which are intended for the carriage of the liquefied gases listed in Appendix A, *List of Cargoes - Tanker for Liquefied Gas*. The requirements are supplementary to those for assignment of main class. The additional hazards considered in this chapter include fire, toxicity, corrosivity, reactivity, low temperature and pressure.

**102** Ships complying with applicable parts of this chapter are considered suitable for the carriage of the volatile chemicals included in Appendix A.

**103** The requirements of this chapter are considered to meet the requirements of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IGC Code, Res. MSC.5(48). The following amendments to the IGC Code are included in this edition of the rules: Res. MSC.30(61) (1992 amendments), Res. MSC.32(63) (1994 amendments), Res. MSC.59(67) (1996 amendments) and Res. MSC.103(73) (2000 amendments).

**104** Gas tankers also intended for carriage of oil shall comply with Ch.3. If only volatile products such as light naphtha shall be carried, equivalent solutions may be accepted on some requirements applying to oil carriers.

#### A 200 Class notations

**201** Ships built according to these rules may be assigned one of the following additional class notations:

- **Tanker for Liquefied Gas**
- **Tanker for C** where **C** indicates the type of cargo for which the ship is classified.

**202** Ships with the class notation **Tanker for C** will be considered in each case, depending on the nature of the cargo to be carried.

**203** Ships fitted with system for onboard regasification of LNG may be given one of the following additional class notations:

- **REGAS-1**: For vessels with regasification plants mainly intended for shuttle operation. Practical information on classification of such installations is given in Classification Note 61.3.
- **REGAS-2**: For vessels with regasification plants mainly intended for continuous operation. Practical information on classification of such installations is given in Classification Note 61.3.

**204** Vessels intended for regasification operation with arrangement for export of natural gas through a submerged turret system may be given the notation **STL** provided that the applicable requirements in Ch.3 Sec.14 are complied with, in addition to the procedures and practical information given in Classification Note 61.3.

#### A 300 Special features notations

**301** Special features notations provide information regarding special features of the ship.

**302** The damage stability standard in accordance with IMO's International Gas Carrier Code as identified by one of the following notations:

- **Ship type 1G**
- **Ship type 2G**

- **Ship type 2PG**
- **Ship type 3G**

will be stated in the Register of vessels classed with DNV.

**303** The minimum and/or maximum acceptable temperature in the tank (°C), maximum acceptable cargo density (kg/m<sup>3</sup>) and the maximum allowable relief valve setting, MARVS (bar), will be stated in the Register of vessels classed with DNV.

#### Example:

A ship may be assigned the additional class notation **Tanker for Liquefied Gas** and the following data may be recorded in the Register of vessels classed with DNV:

**Ship type 2G (-50°C, 1 000 kg/m<sup>3</sup>, 5.0 bar)**

which means that the ship is a type 2G ship according to IMO's International Gas Carrier Code, the lowest acceptable tank temperature is -50°C, maximum acceptable density of the cargo is 1 000 kg/m<sup>3</sup> and MARVS is 5.0 bar.

#### A 400 List of Cargoes

**401** The *List of Cargoes* in Appendix A gives a summary of minimum requirements for each individual cargo. This list will be supplemented and adjusted by the Society as found necessary.

### B. Definitions

#### B 100 Terms

**101** *Accommodation spaces* are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces. Public spaces are those portions of the accommodation which are used as halls, dining rooms, lounges and similar permanently enclosed spaces.

**102** An *air lock* is an enclosed space for entrance between an hazardous area on open deck and a non-hazardous space, arranged to prevent ingress of gas to the non-hazardous space.

**103** *Boiling point* is the temperature at which a product exhibits a vapour pressure equal to the atmospheric barometric pressure.

**104** *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.

**105** *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. If the secondary barrier is part of the hull structure, it may be a boundary of the hold space.

**106** *Cargo control room* is a space used in the control of cargo handling operations and complying with the requirements of Sec.3 B400.

**107** *Cargo process pressure vessels* are process pressure vessels in the cargo handling plant, which during normal operations will contain cargo in the liquid and or gaseous phase.

- 1) Cargo process pressure vessels shall meet the requirements for scantlings, manufacture, workmanship, inspection, non-destructive testing and pressure testing for class I pressure vessels as given in Pt.4 Ch.7.

2) Materials in cargo process pressure vessels, welding procedure tests and production weld tests shall be in accordance with Sec.2 and Sec.5.

**108** *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.

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

**110** *Control stations* are those spaces in which ships' radio or main navigating equipment or the emergency source of power is located, or where the fire recording or fire control equipment is centralized. This does not include special fire control equipment which can be most practically located in the cargo area.

**111** *Ambient temperatures* are the ambient temperatures in air and sea-water used when calculating the steel significant temperature for selection of hull steel grades. See Sec.2 B300.

**112** *Design temperature* for selection of materials in cargo tanks and cargo piping is the lowest temperature which will occur in the respective components during cargo handling. Provisions shall be made so that the temperature cannot be lowered below the design temperature. See Sec.2 B200

**113** *Design vapour pressure  $p_0$*  is the maximum gauge pressure at the top of the tank which has been used in the design of the tank. See Sec.5.

**114** *Flammable products* are identified by an «F» in column «d» in the *List of Cargoes*.

#### **115** *Hazardous area*

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Hazardous areas are divided into Zone 0, 1 and 2 as defined below and according to the area classification specified in Sec.12 C.

##### *Zone 0*

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is present continuously or is present for long periods.

##### *Zone 1*

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is likely to occur in normal operation.

##### *Zone 2*

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

#### **Guidance note:**

The definition of hazardous area is only related to the risk of explosion. In this context, health, safety and environmental issues, i.e. toxicity, is not considered.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

#### **116** *Non-hazardous area*

An area not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

**117** *Spaces not normally entered* are cofferdams, double bottoms, duct keels, pipe tunnels, stool tanks, spaces containing cargo tanks and other spaces where cargo may accumulate.

**118** *Hold space* is the space enclosed by the ship's structure in which a cargo containment system is situated.

**119** *Independent* means that a piping or venting system, for

example, is in no way connected to another system and there are no provisions available for the potential connection to other systems.

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

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

**122** *Liquefied gas* is a cargo with a vapour pressure equal to or above 2.75 bar absolute at 37.8°C.

**123** *Machinery spaces of category A* are those spaces and trunks to such spaces which contain:

- 1) internal combustion machinery used for main propulsion; or
- 2) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
- 3) any oil-fired boiler or oil fuel unit.

**124** *Machinery spaces* are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces; and trunks to such spaces.

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

**126** *Non-cargo process pressure vessels* are process pressure vessels in the cargo handling plant which during normal operations will not contain cargo. Non-cargo process pressure vessels generally contain refrigerants of the halogenated hydrocarbon type in the liquid and or gaseous phase.

— Non-cargo process pressure vessels shall meet the requirements to scantlings, manufacture, workmanship, inspection and testing, and material selection as for pressure vessels as given in Pt.4 Ch.7.

**127** *Oil fuel unit* is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1.8 bar gauge.

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

**129** *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.

**130** *Separate* means that a cargo piping system or cargo vent system, for example, is not connected to another cargo piping or cargo vent system. This separation may be achieved by the use of design or operational methods. Operational methods should not be used within a cargo tank and should consist of one of the following types:

- removing spool pieces or valves and blanking the pipe ends
- arrangement of two spectacle flanges in series with provisions for detecting leakage into the pipe between the two spectacle flanges.

**131** *Service spaces* are spaces outside the cargo area used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store rooms, workshops other than those

forming part of the machinery spaces and similar spaces and trunks to such spaces.

**132** *Steel significant temperature* is the calculated temperature in the hull structures, tank fundamentals and tank stayings when the cargo containment systems and the cargo piping systems are at the design temperature and the ambient temperatures are the design ambient temperatures. See Sec.2 B400.

**133** *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.

**134** *Tank dome* is the upward extension of a portion of the cargo tank. In the case of below deck cargo containment systems the tank dome protrudes through the weather deck or through a tank cover.

**135** *Toxic products* are identified by a T in column «d» of the *List of Cargoes*.

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

**137** *Void space* is the 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.

## C. Documentation

### C 100 General

**101** In 200 are specified the plans and particulars which normally shall be submitted. The drawings shall show clearly that the requirements of this chapter are fulfilled.

**102** Other plans, specifications or information may be required depending on the arrangement and the equipment used in each separate case.

**103** For general requirements for documentation of instrumentation and automation, including computer based control and monitoring, see Pt.4 Ch.9 Sec.1.

### C 200 Plans and particulars

**201** A general arrangement shall be submitted for approval giving location of:

- machinery and boiler spaces, accommodation, service and control station spaces, chain lockers, cofferdams, fuel oil tanks, drinking and domestic water tanks and stores
- cargo tanks and cargo containment systems
- cargo pump and compressor rooms
- cargo control rooms
- cargo piping with shore connections including stern loading and discharge arrangements and emergency cargo dumping arrangement, if fitted
- cargo hatches, vent pipes and any other openings to the cargo tanks
- ventilating pipes, doors and openings to cargo pump rooms, cargo compressor rooms and other hazardous areas
- doors, air locks, hatches, ventilating pipes and openings, hinged scuttles which can be opened, and other openings to non-hazardous areas within and adjacent to the cargo area including spaces in and below the forecastle
- entrances, air inlets and openings to accommodation, service and control station spaces
- hazardous areas of zone 0, 1 and 2, and their extent.

**202** Plans of the cargo containment system with the following particulars shall be submitted for approval:

- drawing of cargo tanks including information on non-de-

structive testing of welds and strength and tightness testing of tanks

- drawings of support and staying of independent tanks
- drawing of antifoatation arrangement for independent tanks
- specification of materials in cargo tanks and cargo piping systems
- specifications of welding procedures for cargo tanks
- specification of stress relieving procedures for independent tanks type C (thermal or mechanical)
- specification of design loads and structural analysis of cargo tanks
- a complete stress analysis shall be submitted for independent tanks, type B and type C
- detailed analytical calculation of hull and tank system for independent tanks, type B
- specification of cooling-down procedure for cargo tanks
- arrangement and specifications of secondary barriers, including method for periodically checking of tightness
- documentation of model tests of primary and secondary barriers of membrane tanks
- drawings and specifications of tank insulation
- drawing of marking plate for independent tanks.

**203** Plans of the following piping systems shall be submitted for approval:

- drawings and specifications of cargo and process piping including vapour piping and vent lines of safety relief valves or similar piping, and relief valves discharging liquid cargo from the cargo piping system
- drawings and specifications of offsets, loops, bends and mechanical expansion joints, such as bellows, slip joints (only inside tank) or similar means in the cargo piping
- drawings of flanges and other fittings in the cargo piping system unless in accordance with a recognised standard
- drawings of valves in the cargo piping system, if of a new type or of an unconventional design. Specifications of valve shall be submitted for information. For valves intended for systems with a design temperature of below -55°C, documentation for leak test and functional test at the design temperature (type test) is required
- complete stress analysis of piping system when design temperature is below -110°C
- documentation of type tests for expansion components in the cargo piping system
- specification of materials, welding, post-weld heat treatment and non-destructive testing of cargo piping
- specification of pressure tests (structural and tightness tests) of cargo and process piping
- program for functional tests of all piping systems including valves, fittings and associated equipment for handling cargo (liquid or vapour)
- drawings and specifications of insulation for low temperature piping where such insulation is installed
- specification of electrical bonding of piping
- specification of means for removal of liquid contents from cargo loading and discharging crossover headers and or cargo hoses prior to disconnecting the shore connection.

**204** The following plans and particulars for the safety relief valves shall be submitted for approval:

- drawings and specifications for safety relief valves and pressure/vacuum relief valves and associated vent piping
- calculation of required cargo tank relief valve capacity
- specification of procedures for changing of set pressures of cargo tank safety relief valves if such arrangements are contemplated.

**205** Plans of the following equipment and systems with particulars shall be submitted:

- construction and specifications of pressure relief systems for hold spaces, interbarrier spaces and cargo piping if

- such systems are required
- calculation of hull steel significant temperature when cargo temperature is below  $-20^{\circ}\text{C}$
- specification of tightness test of hold spaces for membrane tank system
- arrangement and specifications of means for maintaining the cargo tank vapour pressure below MARVS (cooling plant, gas burning arrangement, etc.)
- drawings showing location and construction of air locks with alarm equipment
- drawings of gastight bulkhead stuffing boxes
- arrangements and specifications of mechanical ventilation systems for spaces in the cargo area, giving capacity and location of fans and their motors. Drawings and material specifications of rotating parts and casings for fans and portable ventilators
- drawings and specifications of protection of hull steel beneath liquid piping where liquid leakage may be anticipated, such as at shore connections and at pump seals
- arrangement and specifications of piping systems for gas freeing and purging of cargo tanks
- arrangement of piping for inerting of interbarrier and hold spaces (not required for independent tanks type C)
- specifications of equipment for provision of dry inert gas (dry air in hold spaces containing independent tanks type C) for the maintenance of an inert atmosphere in interbarrier and hold spaces
- for fixed gas detection and alarm systems: Specification and location of detectors, alarm devices and call points, and cable routing layout drawing
- location of gas sampling points within cargo tanks
- bilge and drainage arrangements in cargo pump rooms, cargo compressor rooms, cofferdams, pipe tunnels, hold spaces and interbarrier spaces
- drawings and specifications of inert gas plants if installed, see Sec.18.

**206** Plans of electrical installations giving the following particulars shall be submitted for approval:

- area classification drawing(s)
- drawing(s) showing location of all electrical equipment in hazardous areas
- single line diagram for intrinsically safe circuits and data for verification of the compatibility between the barrier and the field component
- list of explosion protected equipment with reference to drawings together with certificates
- maintenance manual as specified in Sec.12 E101, for electrical installations in hazardous areas shall be submitted for approval.

**207** The following plans and particulars regarding fire protection and extinction shall be submitted for approval:

- arrangement for the remote starting of the fire pumps and connecting them to the fire main from the bridge or other control station outside the cargo area
- arrangement and specifications of water spray systems, including pipes, valves, nozzles and other fittings
- arrangement and specifications of dry chemical powder fire extinguishing systems
- arrangement and specifications of fixed fire smothering installations in closed hazardous areas.

**208** The following documentation of damage stability shall be submitted for approval:

- preliminary damage stability calculations
  - final damage stability calculations
- Not required in case of approved limit curves, or if approved lightweight data are not less favourable than estimated lightweight data.

The following documentation shall be submitted for information:

- internal watertight integrity plan.

Detailed description of stability documentation is given in Classification Note No. 20.1.

**209** The following control and monitoring systems shall be approved by the Society:

- cargo and vapour temperature control and monitoring system
- cargo tank level measurement system
- cargo tank overflow protection system
- cargo valves and pumps control and monitoring system
- cargo and vapour pressure control and monitoring system
- emergency shut-down system
- flammable gas detection system (permanent system only)
- inert gas control and monitoring system
- oxygen indication equipment (permanent system only).

For requirements to documentation, see Pt.4 Ch.9.

## D. Tank Types

### D 100 Integral tanks

**101** Integral tanks form a part of the ship's hull and are influenced in the same manner and by the same loads which stress the adjacent hull structure.

**102** The design vapour pressure  $p_0$  as defined in B114, is normally not to exceed 0.25 bar. If, however, the hull scantlings are increased accordingly,  $p_0$  may be increased to a higher value, but less than 0.7 bar.

**103** Integral tanks may be used for cargoes with a boiling point not below  $-10^{\circ}\text{C}$ . A lower temperature may be accepted subject to special consideration.

### D 200 Membrane tanks

**201** Membrane tanks are non-self-supporting tanks which consist of a thin layer (membrane) supported through insulation by the adjacent hull structure. The membrane is designed in such a way that thermal and other expansion or contraction is compensated for without undue stressing of the membrane.

**202** The design vapour pressure  $p_0$  is normally not to exceed 0.25 bar. If, however, the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation,  $p_0$  may be increased to a higher value but less than 0.7 bar.

**203** The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or in which membranes are included or incorporated in insulation. Such designs require, however, special consideration by the Society. In any case the thickness of the membranes shall normally not exceed 10 mm.

### D 300 Semi-membrane tanks

**301** Semi-membrane tanks 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, 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.

**302** The design vapour pressure  $p_0$  is normally not to exceed 0.25 bar. If, however, the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation,  $p_0$  may be increased to a higher value but less than 0.7 bar.

### D 400 Independent tanks

**401** Independent tanks do not form a part of the ship's hull. An independent tank is built and installed in such a way that the influence on the tank of the hull's deformation and stresses is minimized. An independent tank is not essential to the hull strength. An independent tank is normally to have longitudinally rigid fixture to the ship in only one transverse plane.

### D 500 Independent tanks type A

**501** Independent tanks type A are designed primarily using recognised standards of classical ship-structural analysis procedures. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure  $p_0$  shall be less than 0.7 bar.

### D 600 Independent tanks type B

**601** Independent tanks type B are 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 (gravity tanks), the design vapour pressure  $p_0$  shall be less than 0.7 bar.

### D 700 Independent tanks type C

**701** Independent tanks type C (also referred to as pressure vessels) are tanks meeting pressure vessel criteria and having a design vapour pressure  $p_0$  not less than:

$$p_0 = 2 + A C (\rho)^{1.5} \quad (\text{bar})$$

$$A = 0.0185 \left( \frac{\sigma_m}{\Delta \sigma_a} \right)^2$$

- $\sigma_m$  = design primary membrane stress  
 $\Delta \sigma_A$  = allowable dynamic membrane stress (double amplitude at probability level  $Q = 10^{-8}$ )  
 = 55 N/mm<sup>2</sup> for ferritic-perlitic, martensitic and austenitic steels  
 = 25 N/mm<sup>2</sup> for aluminium alloy (5083-0)  
**C** = a characteristic tank dimension to be taken as the greatest of the following:  $h$ ,  $0.75 b$ , or  $0.45 l$   
**h** = height of tank exclusive dome (dimension in ship's vertical direction) (m)  
**b** = width of tank (dimension in ship's transverse direction) (m)  
**l** = length of tank (dimension in ship's longitudinal direction) (m)  
 $\rho$  = the relative density of the cargo at the reference temperature ( $\rho = 1$  for fresh water of 4°C).

However, the Society may allocate a tank complying with this criterion to type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

**702** If the carriage of products not covered by Appendix A is intended, the relative density of which exceeds 1.0, 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 701 i.e.:

$$\Delta \sigma_m \leq \Delta \sigma_A$$

The dynamic pressure differential  $\Delta p$  shall be calculated as follows:

$$\Delta p = \frac{\rho}{1.02 \cdot 10^4} (a_{\beta_1} Z_{\beta_1} - a_{\beta_2} Z_{\beta_2}) \quad (\text{bar})$$

where  $\rho$ ,  $a_\beta$ ,  $Z_\beta$  are as defined in Sec.5 A706, see also the sketches below.  $a_{\beta_1}$  and  $Z_{\beta_1}$  are the  $a_\beta$ - and  $Z_\beta$ - values giving the maximum liquid pressure ( $P_{gd}$ ) max.

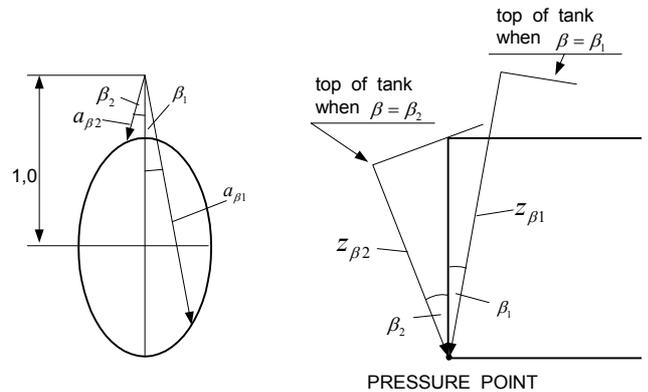
$a_{\beta_2}$  and  $Z_{\beta_2}$  are the  $a_\beta$ - and  $Z_\beta$ - values giving the minimum

liquid pressure ( $P_{gd}$ ) min.

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 sketches below.

### D 800 Internal insulation tanks

**801** Internal insulation tanks are non-self-supporting and consist of thermal insulation materials which contribute to the cargo containment and are supported by the structure of the adjacent inner hull or of an independent tank. The inner surface of the insulation is exposed to the cargo.



**Fig. 1**  
Acceleration ellipse used to evaluate pressure differential

**802** The two categories of internal insulation tanks are:

- Type 1 tanks are tanks in which the insulation or a combination of the insulation and one or more liners function *only* as the primary barrier. The inner hull or an independent tank structure should function as the secondary barrier when required.
- Type 2 tanks are tanks in which the insulation or a combination of the insulation and one or more liners function as *both* the primary and the secondary barrier and where these barriers are clearly distinguishable.

The term “liner” means a thin, non-self-supporting, metallic, non-metallic or composite material which forms part of an internal insulation tank in order to enhance its fracture resistance or other mechanical properties. A liner differs from a membrane in that it alone is not intended to function as a liquid barrier.

**803** Internal insulation tanks shall be of suitable materials enabling the cargo containment system to be designed using model tests and refined analytical methods as required in Sec.5 J.

**804** The design vapour pressure  $p_0$  is not normally to exceed 0.25 bar. If, however, the cargo containment system is designed for a higher vapour pressure,  $p_0$  may be increased to such higher value, but not exceeding 0.7 bar if the internal insulation tanks are supported by the inner hull structure. However, a design vapour pressure of more than 0.7 bar may be accepted by the Society provided the internal insulation tanks are supported by suitable independent tank structures.

## E. Signboards

### E 100 References

**101** Signboards are required by the rules in:

- Sec.3 C109. Regarding plates bolted to boundaries facing the cargo area which can be opened for removal of machinery. These shall be fitted with signboards informing

- 
- that plates shall be kept closed unless ship is gas-free.
  - Sec.8. Regarding marking plates for independent tanks.
  - Sec.10 A108. Regarding pumps and compressors which shall not be started before the ventilation system in the electric motor room has been in operation for 15 minutes. Ventilation system for pump and compressor rooms shall be in operation when pumps and compressors are running.
  - Sec.11 B401. Regarding marking of controls for carbon dioxide system.
  - Sec.12 C101. Regarding opening of a lighting fitting. Before opening, its supply circuit shall be disconnected.
  - Sec.12 C102. Regarding spaces where the ventilation must be in operation before the light is turned on.
  - Sec.12 C103. Regarding portable electrical equipment supplied by flexible cables. This equipment shall not be used in areas where there is gas danger.
  - Sec.12 C104. Regarding welding apparatus. These shall not be used unless the working space and adjacent spaces are gas-free.
  - Sec.16 B210, 211, 212 and C106. Regarding gas operation of propulsion machinery.

## SECTION 2 MATERIALS AND HULL STRENGTH

### A. General

#### A 100 Selection and testing

**101** Detailed requirements for chemical composition, mechanical properties, notch toughness etc. for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo piping, secondary barriers and contiguous hull structures associated with the transportation of the products are found in Pt.2.

**102** The manufacture, testing, inspection and documentation shall be in accordance with Pt.2 and the specific requirements given in this section.

**103** Materials other than those covered by Pt.2 and referred to in this section may be accepted subject to approval in each separate case.

**104** For certain cargoes as specified in Sec.15 or in the *List of Cargoes*, special requirements for materials apply.

**105** Where postweld heat treatment is specified or required, the properties of the base material shall be determined in the heat-treated condition in accordance with the applicable Tables D1 to D4 and the weld properties should be determined in the heat-treated condition in accordance with Pt.2 Ch.3 Sec.5 and Sec.5 L. In cases where a postweld heat treatment is applied, the test requirements may be modified at the discretion of the Society.

**106** Requirements for welding procedure and production tests are given in Sec.5 and Sec.6.

The requirements for welding consumables are given in Pt.2 Ch.3.

**107** Thermal insulation materials shall be in compliance with the requirements of Sec.7.

### B. Temperatures for Selection of Materials

#### B 100 General

**101** The requirements to material qualities are determined on the basis of the lowest temperatures in the material. These temperatures are determined as specified in 200-400.

#### B 200 Design temperature

**201** Design temperature for cargo tanks is the minimum temperature at which cargo may be loaded or transported in the cargo tanks. Provisions to the satisfaction of the Society shall be made so that the tank or cargo temperature cannot be lowered below the design temperature. The design temperature for the cargo tanks may be stated in the Register of vessels classed with DNV. See Sec.1 A300.

**202** Design temperature for cargo piping, cargo process pressure vessels and all associated equipment is the minimum temperature which can occur in the systems and components during cargo handling operations.

**203** Design temperature for a complete or partial secondary barrier is equal to the boiling point of the most volatile cargo.

#### B 300 Ambient temperatures

**301** For the purpose of calculating the inner hull temperatures the ambient temperatures are generally 5°C for air and 0°C for sea water for world wide service.

However, higher values of the ambient temperatures may be

accepted by the Society for ships operating in restricted areas.

Conversely, lesser values of the ambient temperatures may be fixed for ships trading occasionally or regularly to areas in latitudes where such lower temperatures are expected during the winter months.

#### Guidance note:

Attention is drawn upon the fact that lesser values of the ambient temperatures than 5°C for air and 0°C for sea water may be fixed by National Authorities when calculating inner hull steel temperatures.

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#### Guidance note:

If an IMO Certificate of Fitness is issued, the ambient temperatures used when calculating the inner hull steel temperatures will be stated on the Certificate.

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**302** For the purpose of calculating the outer hull steel temperatures, the ambient temperatures are generally 5°C for air and 0°C for sea water for world wide service.

#### B 400 Steel significant temperature

**401** Steel significant temperature is the minimum temperature of the hull structure, tank foundations and tank stayings determined by calculations as detailed in 500, taking into account the efficiency of any insulation and means of heating if accepted according to 600. The calculations shall be made assuming that:

- the cargo tanks are at their design temperature according to 201
- if a complete or partial secondary barrier is required, the complete or partial secondary barrier is at the design temperature according to 203
- the ambient temperatures are those given in 301 and 302 for inner and outer hull respectively
- piping systems are at their design temperatures.

#### B 500 Temperature calculations

**501** If the design temperature of the cargo tanks is lower than -10°C, calculations of the steel significant temperatures referred to in 400 shall be submitted. The calculations shall be made assuming still air and still water. Except as permitted by 600 no credit will be given for means of heating.

If a complete or partial secondary barrier is required, the cooling effect of the rising boil-off vapour from the leaked cargo shall be considered in the heat transmission studies. For structural members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

**502** When account is taken of insulation in the heat transmission studies, the insulation shall comply with the requirements in Sec.7.

#### B 600 Heating of hull structural material

**601** For ambient temperature conditions of 5°C for air and 0°C for sea-water, approved means of heating transverse hull structural material may be used to ensure that the temperatures of this material do not fall below the steel significant temperature. If lower ambient temperatures are specified according to 301, approved means of heating may also be used for longitudinal hull structural material, provided this material remains suitable for the temperature conditions of 5°C for air and 0°C for sea-water without heating. Such means of heating shall comply with the following requirements:

- 1) Sufficient heat shall be available to maintain the hull structure above the steel significant temperature in the conditions referred to in 400 and 500.
- 2) The heating system shall be arranged so that, in the event of a failure in any part of the system, stand-by heating can be maintained equal to not less than 100% of the theoretical heat load.
- 3) The heating system shall be considered as an essential auxiliary.
- 4) The design and construction of the heating system shall be approved.
- 5) The heating system shall be tested for heat output and heat distribution.

of bulkheads and lower decks separating spaces for cargo tanks.  
In the lower temperature range, channels or cofferdam structures may be fitted for internal heating.

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## C. Hull Materials

### C 100 Inner hull structure

**101** The inner hull structure includes inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

**102** Materials in the inner hull structure which are subject to reduced temperature due to the cargo, and which do not form part of the secondary barrier, shall be in accordance with Table C1 if the steel significant temperature calculated according to B400 is below 0°C.

**Guidance note:**

To prevent unnecessary cooling-down of the surrounding hull structure, strip insulation may be arranged along the edges on both sides

### C 200 Outer hull structure

**201** The outer hull structure includes the shell and deck plating of the ship and all stiffeners attached thereto.

**202** The materials in the outer hull structure shall be in accordance with Pt.3 Ch.1 Sec.2, unless then calculated temperature of the material in the design condition (see B400) is below -5°C due to the effect of the low temperature cargo, in which case the material shall be in accordance with Table C1 assuming the ambient air and sea temperatures of 5°C and 0°C respectively.

In the design condition the complete or partial secondary barrier is assumed to be at the cargo temperature at atmospheric pressure and for tanks without secondary barriers, the primary barrier is assumed to be at the cargo temperature.

### C 300 Secondary barrier

**301** Hull material forming the secondary barrier shall be in accordance with Table D2. Metallic materials used in secondary barriers not forming part of the hull structure should be in accordance with Table D2 or D3 as applicable. Insulation materials forming a secondary barrier shall comply with the requirements of Sec.7 C200. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Table D2 should be carried into the adjacent deck or side shell plating, where applicable to a suitable extent.

Table C1 Plates and sections for hull structures required by 100 and 200							
Steel significant temperature (°C)	Maximum thickness (mm) for steel grades in accordance with Pt.2 Ch.2 Sec.1						
	NV A	NV B	NV D	NV E	NV AH <sup>1)</sup>	NV DH <sup>1)</sup>	NV EH <sup>1)</sup>
0 and above <sup>2)</sup> -5 and above <sup>3)</sup>	Normal practice						
Down to -5	15	25	30	50	25	45	50
Down to -10	x	20	25	50	20	40	50
Down to -20	x	x	20	50	x	30	50
Down to -30	x	x	x	40	x	20	40
Below -30	In accordance with Table D2 except that the thickness limitation given in Table D2 and in footnote <sup>2)</sup> of that table does not apply.						
«x» means steel grade not to be used.							
1) H means "High strength steel".							
2) For the purpose of 100.							
3) For the purpose of 200.							

## D. Materials for Cargo Piping, Cargo Tanks, Cargo Process Pressure Vessels and Secondary Barriers

### D 100 Material requirements

**101** Materials for cargo piping, cargo tanks, cargo process pressure vessels and secondary barriers shall comply with the minimum requirements given in the following tables:

**Table D1:** Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

**Table D2:** 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 D3:** 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 D4:** Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to -165°C.

**102** The detailed requirements for materials as specified in Tables D1 to D4 are found as follows:

- plates and sections: Pt.2 Ch.2 Sec.2
- pipes: Pt.2 Ch.2 Sec.4
- forgings: Pt.2 Ch.2 Sec.5
- castings: Pt.2 Ch.2 Sec.7.

**103** Aluminium alloy type 5083 (ISO Al Mg 4.5 Mn) and 36% nickel alloy steel, will be approved in each separate case.

<b>Table D1 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>		
<b>CHEMICAL COMPOSITION AND HEAT TREATMENT</b>		
Carbon-manganese steel. Fully killed. Fine grain steel where thickness exceeds 20 mm Small additions of alloying elements by agreement with the Society Composition limits to be approved by the Society Normalized, or quenched and tempered <sup>2)</sup>		
<b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>		
Plates	Each "piece" to be tested	
Sections and forgings	Batch test	
Tensile properties	Specified minimum yield stress not to exceed 410 N/mm <sup>2</sup> <sup>3)</sup>	
<b>CHARPY V-NOTCH TEST</b>		
Plate	Transverse test pieces. Minimum average energy value (E) 27 J	
Sections and forgings	Longitudinal test pieces. Minimum average energy value (E) 41 J	
Test temperature	Thickness t (mm)	Test temperature (°C)
	t ≤ 20	0
	20 < t ≤ 40	-20
1) For seamless pipes and fittings, normal practice applies. The use of longitudinally and spirally welded pipes and welded elbows, T-pieces, etc. shall be especially approved by the Society. 2) A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Society. 3) Materials with specified minimum yield stress exceeding 410 N/mm <sup>2</sup> may be specially approved by the Society. For these materials, particular attention should be given to the hardness of the weld and heat affected zone.		

<b>Table D2 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 25 mm <sup>2)</sup></b>															
<b>STEEL TYPE AND HEAT TREATMENT</b>															
Carbon-manganese steel. Fully killed. Aluminium treated fine grain steel.															
<b>CHEMICAL COMPOSITION (LADLE ANALYSIS)</b>															
C (%)	Mn (%)	Si (%)	S (%)	P (%)											
0.16 maximum <sup>3)</sup>	0.70 to 1.60	0.10 to 0.50	0.035 maximum	0.035 maximum											
Optional additions: Alloys and grain refining elements may be generally in accordance with the following:															
Ni (%)	Cr (%)	Mo (%)	Cu (%)	Nb (%)	V (%)										
0.80 maximum	0.25 maximum	0.08 maximum	0.35 maximum	0.05 maximum	0.10 maximum										
Normalized or quenched and tempered <sup>4)</sup>															
<b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>															
Plates	Each "piece" to be tested														
Sections	Batch test														
<b>CHARPY V-NOTCH TEST</b> Test temperatures 5°C below the design temperature or -20°C whichever is lower															
Plates	Transverse test pieces. Minimum average energy value (E) 27 J														
Sections and forgings <sup>1)</sup>	Longitudinal test pieces. Minimum average energy value (E) 41 J														
1) The Charpy V-notch and chemistry requirements for forgings may be specially considered. 2) For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows: <table border="0" style="width: 100%;"> <tr> <td style="width: 20%;">Material thickness (mm)</td> <td>Test temperature (°C)</td> </tr> <tr> <td>25 &lt; t ≤ 30</td> <td>10°C below design temperature</td> </tr> <tr> <td>25 &lt; t ≤ 30</td> <td>10°C below design temperature or -20°C whichever is lower</td> </tr> <tr> <td>30 &lt; t ≤ 35</td> <td>15°C below design temperature or -20°C whichever is lower</td> </tr> <tr> <td>35 &lt; t ≤ 40</td> <td>20°C below design temperature</td> </tr> </table> The impact energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values will be specially considered. 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. 3) By special agreement with the Society, the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than - 40°C. 4) A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval.						Material thickness (mm)	Test temperature (°C)	25 < t ≤ 30	10°C below design temperature	25 < t ≤ 30	10°C below design temperature or -20°C whichever is lower	30 < t ≤ 35	15°C below design temperature or -20°C whichever is lower	35 < t ≤ 40	20°C below design temperature
Material thickness (mm)	Test temperature (°C)														
25 < t ≤ 30	10°C below design temperature														
25 < t ≤ 30	10°C below design temperature or -20°C whichever is lower														
30 < t ≤ 35	15°C below design temperature or -20°C whichever is lower														
35 < t ≤ 40	20°C below design temperature														

**Guidance note:**

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with Table D3 may be necessary.

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<b>Table D3 Plates, sections and forgings <sup>1)</sup> for cargo tanks secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C <sup>2)</sup>, Maximum thickness 25 mm <sup>3)</sup></b>		
<i>Minimum design temperature (°C)</i>	<i>Chemical composition <sup>4)</sup> and heat treatment</i>	<i>Impact test temperature (°C)</i>
-60	1.5% nickel steel -normalized	-65
-65	2.25% nickel steel -normalized or normalized and tempered <sup>5)</sup>	-70
-90	3.5% nickel steel -normalized or normalized and tempered <sup>5)</sup>	-95
-105	5% nickel steel -normalized or normalized and tempered <sup>5) 6)</sup>	-110
-165	9% nickel steel -double normalized and tempered or quenched and tempered	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution heat treated <sup>7)</sup>	-196
-165	Aluminium alloys; such as type 5083 annealed	Not required
-165	Austenitic Fe-Ni alloy (36% nickel) Heat treatment as agreed	Not required
<b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>		
Plates	Each "piece" to be tested	
Sections and forgings	Batch test	
<b>CHARPY V-NOTCH TEST</b>		
Plates	Transverse test pieces. Minimum average energy value (E) 27 J	
Sections and forgings	Longitudinal test pieces. Minimum average energy value (E) 41 J	
<p>1) The impact test required for forgings used in critical applications will be subject to special consideration.</p> <p>2) The requirements for design temperatures below -165°C shall be specially agreed.</p> <p>3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni, and 5% Ni with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:  Material thickness (mm)    Test temperature (°C)  25 &lt; t ≤ 30                    10°C below design temperature  30 &lt; t ≤ 35                    15°C below design temperature  35 &lt; t ≤ 40                    20°C below design temperature  In no case shall the test temperature be above that indicated in the table. The energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values will be specially considered. For 9% Ni, austenitic stainless steels and aluminium alloys, thicknesses greater than 25 mm may be used at the discretion of the Society.</p> <p>4) The chemical composition limits shall be approved by the Society.</p> <p>5) A lower minimum design temperature for quenched and tempered steels may be specially agreed.</p> <p>6) A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to -165°C upon special agreement with the Society, provided that the impact tests are carried out at -196°C.</p> <p>7) The impact test is required only for design temperature below -105°C.</p>		

<b>Table D4 Pipes (seamless and welded) <sup>1)</sup>, forgings <sup>2)</sup> and castings <sup>2)</sup> for cargo and process piping for design temperatures below 0°C and down to -165°C <sup>3)</sup>. Maximum thickness 25 mm</b>			
<i>Minimum design temperature (°C)</i>	<i>Chemical composition <sup>5)</sup> and heat treatment</i>	<i>Impact test</i>	
		<i>Test temperature (°C)</i>	<i>Minimum average energy (E) (J)</i>
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed <sup>6)</sup>	4)	27
-65	2.25% nickel steel. Normalized or normalized and tempered <sup>6)</sup>	-70	34
-90	3.5% nickel steel. Normalized or normalized and tempered <sup>6)</sup>	-95	34
-165	9% nickel steel <sup>7)</sup> . Double normalized and tempered or quenched and tempered	-196	41
	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution heat treated <sup>8)</sup>	-196	41
	Aluminium alloys, such as type 5083 annealed		Not required
<b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>			
Each batch to be tested			
<b>IMPACT TEST Longitudinal test pieces</b>			
<p>1) The use of longitudinally or spirally welded pipes and welded elbows, T-pieces, etc shall be especially approved by the Society.</p> <p>2) The requirements for forgings and castings may be subject to special consideration.</p> <p>3) The requirements for design temperatures below -165°C shall be specially agreed with the Society.</p> <p>4) The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.</p> <p>5) The composition limits should be approved by the Society.</p> <p>6) A lower design temperature may be specially agreed for quenched and tempered materials.</p> <p>7) This chemical composition is not suitable for castings.</p> <p>8) Impact tests are required only for design temperature below -105°C.</p>			

## E. Documentation of Material Quality and Testing of Pipe and Pipe Fittings

### E 100 General

**101** The materials used in cargo piping systems shall be furnished with documentation according to Table E1. For definition of material documentation, see Pt.1 Ch.1 Sec.4.

<b>Table E1 Documentation of material quality and testing</b>							
<i>Type</i>	<i>Material</i>	<i>Piping system</i>	<i>Nominal diameter (mm)</i>	<i>Design temperature (°C)</i>	<i>Type of documentation</i>		
					<i>NV certificate</i>	<i>Works certificate</i>	<i>Test report</i>
Pipes		Pressure	> 25		x		
		Pressure	≤ 25			x	
		Open ended				x	
Elbows, T-pieces etc., fabricated by welding	Steel	Pressure				x	
		Open ended					x
Flanges		Pressure				x	
		Open ended					x
Bodies of valves and fittings, pump housings, source materials of steel expansion bellows, other pressure containing components not considered as pressure vessels	Steel	Pressure	> 100	< -55	x		
		Pressure	> 100	≥ -55		x	
		Pressure	≤ 100			x	
	Copper alloys	Open ended					x
		Pressure	>50				x
		Pressure	≤ 50				x
		Open ended					x
Nuts and bolts	Steel						x

## F. Hull Strength

### F 100 Emergency towing

**101** Emergency towing arrangements for gas carriers of 20 000 tonnes deadweight and above shall comply with requirements in Pt.5 Ch.3 Sec.2 C600.

## SECTION 3 DAMAGE STABILITY AND SHIP ARRANGEMENTS

### A. Damage Stability and Location of Cargo Tanks

#### A 100 General

**101** If a ship is intended to carry more than one product listed in Appendix A, *List of Cargoes*, the standard of damage shall correspond to that product having the most stringent ship type requirement. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

**102** Solid ballast is not normally to be used in double bottom spaces in the cargo area. Where, however, because of stability considerations the fitting of solid ballast in such spaces becomes unavoidable, then the quantity and its disposition shall be governed by the need to ensure that impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

#### A 200 Damage stability

**201** The ship shall meet the damage stability requirements of Chapter 2 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk either for:

- Ship type 1G
- Ship type 2G
- Ship type 2PG or
- Ship type 3G.

**202** Maximum allowable VCG curve(s), for the purpose of checking damage stability compliance, shall be included in the stability manual, unless one of the following alternatives are preferred:

- 1) The loading manual includes, in approved form, all the conditions intended to be used.
- 2) The loading computer, intended for conditions at sea, includes approved software functions for damage stability.

Reference is made to Pt.6 Ch.9 Sec.1 and Pt.6 Ch.9 Sec.2.

**203** As far as practicable, tunnels, ducts or pipes which may cause progressive flooding in case of damage, shall be avoided in the damage penetration zone. If this is not possible, arrangements shall be made to prevent progressive flooding to volumes assumed intact. Alternatively, these volumes shall be assumed flooded in the damage stability calculations.

**204** The scantlings of tunnels, ducts, pipes, doors, staircases, bulkheads and decks, forming watertight boundaries, shall be adequate to withstand pressure heights corresponding to the deepest equilibrium waterline in damaged condition.

#### A 300 Location of cargo tanks

**301** Tanks intended for carriage of cargoes for which ship type 1G is required shall be located at a minimum distance from the ship's side shell plating of  $B/5$  or 11.5 m, whichever is less, measured inboard from the ship's side at right angle to the centre line at the level of the summer load line, and at a vertical distance from the moulded line of the bottom shell plating at centre line not less than:

- the rule height for the centre girder in dry cargo ships, see Pt.3 Ch.1

— the lesser of  $B/15$  and 2 m

and nowhere less than 760 mm from the shell plating. See Fig.1.

**302** Tanks intended for carriage of cargoes for which **Ship types 2G/2PG or 3G** are required shall be located at a vertical distance from the moulded line of the bottom shell plating at centreline not less than:

- the rule height of centre girder in dry cargo ships, see Pt.3 Ch.1
- the lesser of  $B/15$  and 2 m

and nowhere less than 760 mm from the shell plating. See Fig.1.

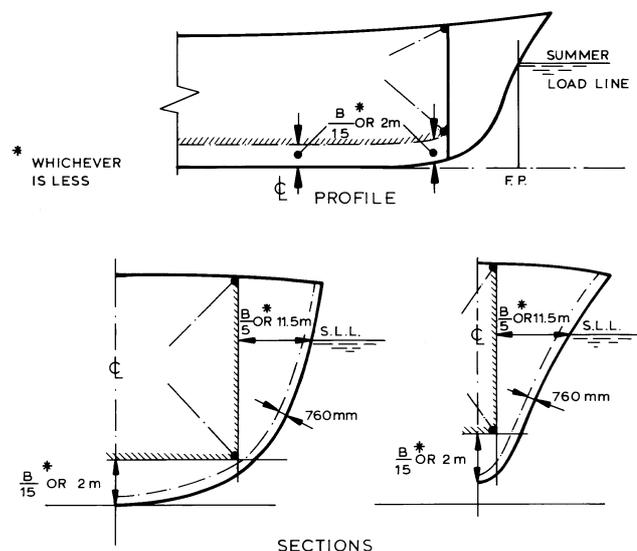
**303** For membrane and semi-membrane tanks the distances given in 301 and 302 shall be measured to the longitudinal bulkheads and the inner bottom respectively and for independent tanks to the side and bottom of the cargo tanks. For internal insulation tanks the extent of damage shall be measured to the supporting tank plating.

**304** Except for cargoes requiring **Ship type 1G** cargo tank location, suction wells installed in cargo tanks may protrude below the distance from the outer bottom as given in 302, provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25% of the depth of the double bottom or 350 mm, whichever is less.

#### Guidance note:

The International Code for the Construction and Equipment of Ships carrying Liquefied Gases in Bulk gives in 1.1.4.1 to 1.1.4.4 additional requirements for the location of flammable liquid cargoes when simultaneously carrying cargoes requiring **Ship type 1G or 2G/2PG** cargo tank location.

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**Fig. 1**  
**Tank location requirements as set out in 300**

## B. Location and Separation of Spaces

### B 100 Segregation of the cargo area

**101** Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces and control stations, chain lockers, drinking and domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A, other than those deemed necessary by the Society for the safety or navigation of the ship.

**102** Where cargo is carried in a cargo containment system not requiring a secondary barrier, segregation of hold spaces from spaces referred to in 101, or spaces either below or outboard of the hold spaces, may be effected by cofferdams, fuel oil tanks, or a single bulkhead of all welded construction forming an A-60 class division. A gastight A-0 class division is satisfactory if there is no source of ignition or fire hazard in the adjoining spaces.

**103** Where cargo is carried in a cargo containment system requiring a secondary barrier, segregation of hold spaces from spaces referred to in 101, or spaces either below or outboard of the hold spaces which contain a source of ignition or fire hazard, shall be effected by cofferdams or fuel oil tanks. If there is no source of ignition or fire hazard in the adjoining space, segregation may be by a single A-0 class division which is gas-tight.

**104** When cargo is carried in a cargo containment system requiring a secondary barrier at temperatures below  $-10^{\circ}\text{C}$ , hold spaces shall be segregated from the sea by a double bottom, and when the cargo temperature is below  $-55^{\circ}\text{C}$ , the ship is also to have longitudinal bulkheads forming side tanks.

**105** Any piping system which may contain cargo or cargo vapour, shall:

- be segregated from other piping systems, except where inter-connections are required for cargo related operations, such as purging, gas freeing or inerting. In such cases precautions shall be taken to ensure that cargo or cargo vapour cannot enter such other piping systems through the inter-connections
- except as provided in Sec.16, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo pump room or cargo compressor space
- be connected into the cargo containment system directly from the open deck, except that the pipes installed in a vertical trunkway or equivalent may be used to traverse void spaces above a cargo containment system, and except that pipes for drainage, venting or purging may traverse cofferdams
- except for bow or stern loading provisions in accordance with C103 and emergency cargo jettisoning systems in accordance with 106, and except in accordance with Sec.16, be located in the cargo area above the open deck
- except for thwartship shore connection piping not subject to internal pressure at sea, be located inboard of the transverse tank location requirements given in A300.

**106** Any emergency cargo jettisoning piping system shall comply with 105 as appropriate and may be led aft externally 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 isolation from the cargo piping shall be provided within the cargo area.

**107** Arrangements shall be made for sealing the weather decks in way of openings for cargo containment systems.

### B 200 Accommodation, service and control station spaces

**201** No accommodation space, service space or control sta-

tion shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations which face the cargo area shall be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.

**202** Where a corner-to-corner situation occurs between a non-hazardous space and a cargo tank, a cofferdam created by a diagonal plate across the corner on the non-hazardous side, may be accepted as separation.

Such cofferdams shall be:

- ventilated if accessible
- filled with a suitable compound if not accessible.

### B 300 Cargo pump rooms and cargo compressor rooms

**301** Cargo pump rooms and cargo compressor rooms shall be situated above the weather deck and located within the cargo area unless specially approved by the Society. Cargo compressor rooms shall be treated as cargo pump rooms for the purpose of fire protection according to Ch.3 Sec.7.

**302** When cargo pump rooms and cargo compressor rooms are permitted to be fitted above or below the weather deck at the after end of the aftermost hold space or at the forward end of the forwardmost hold space, the limits of the cargo area as defined in Sec.1 B100 shall be extended to include the cargo pump rooms and cargo compressor rooms for the full breadth and depth of the ship and deck areas above those spaces.

**303** Where the limits of the cargo area are extended by 302, the bulkhead which separates the cargo pump rooms and cargo compressor rooms from accommodation and service spaces, control stations and machinery spaces of category A shall be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

The same condition is also to be satisfied when cargo pump-rooms and compressor rooms, fitted within the cargo area, have a bulkhead in common with accommodation and service spaces, control stations and machinery spaces of category A.

**304** 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 the gas seal shall be fitted in way of the bulkhead or deck.

### B 400 Cargo control rooms

**401** Any cargo control room shall be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations provided the following conditions are complied with:

- the cargo control room is a gas safe space
- if the entrance complies with C102, the control room may have access to the spaces described above
- if the entrance does not comply with C102 the control room shall have no access to the spaces described above and the boundaries to such spaces shall be insulated to A-60 class integrity.

**402** If the cargo control room is designed to be a gas-safe space, instrumentation is, as far as possible, to be by indirect reading systems, and is in any case to be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detector within the cargo control room will not violate the gas safe space if installed in accordance with Sec.13 B312.

**403** If the cargo control room for ships carrying flammable cargoes is a gas-dangerous space, sources of ignition shall be excluded. Consideration shall be paid to the safety characteristics of any electrical installations.

## C. Arrangement of Entrances and other Openings

### C 100 Non-hazardous spaces and accommodation spaces

**101** Access through doors, gastight or otherwise, is not permitted from a gas-safe space to a non-hazardous except for access to service spaces forward of the cargo area through air locks when accommodation spaces are aft.

**102** Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4% of the length of the ship but not less than 3 m from the end of the superstructures or deckhouses facing the cargo area. This distance, however, need not exceed 5 m. Windows and sidescuttles facing the cargo area and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type.

Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the above limits so long as they are so designed that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured. For ships dedicated to the carriage of cargoes which have neither flammable nor toxic hazards, the Society may approve relaxations from the above requirements.

Air outlets are subject to the same requirements as air inlets and air intakes.

**103** Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo shore connection location of bow or stern loading and unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a 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 shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Sidescuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type. In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side shall be kept closed. Where, in the case of small ships, compliance with 102 and this paragraph is not possible, the Society may approve relaxations from the above requirements.

Air outlets are subject to the same requirements as air inlets and air intakes.

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

**105** All air intakes and openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. For toxic gases they shall be operated from inside the space. See also 110.

**106** Access from the open weather deck to non-hazardous spaces in the cargo area shall be located in a non-hazardous zone at least 2.4 m above the weather deck, unless the access is by means of an air lock in accordance with 300.

**107** In order to guard against the danger of hazardous vapours, due consideration shall be given to the location of air intakes and openings into accommodation, machinery spaces, service and control station spaces in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.

Compliance with other relevant paragraphs of this chapter and in particular with 102 and 103, Sec.9 B208 and B209, and Sec.10 A and B, and Sec.12 C where applicable will ensure compliance with this requirement.

**108** Cargo control rooms, stores and other spaces not covered by 102 but located within accommodation, service and control station spaces, may be permitted to have doors facing the cargo area. Where such doors are fitted, the spaces shall not have access to the spaces covered by 102 and the boundaries of the spaces shall be insulated to A-60 class (see Sec.11).

**109** Bolted plates for removal of machinery may be fitted in boundaries facing the cargo area. Such plates shall be insulated to A-60 class (see Sec.11). Signboards giving instruction that the plates shall be kept closed unless the ship is gas-free, shall be posted near the plates.

**110** The requirement for fitting air intakes and openings with closing devices operable from inside the space in ships intended to carry toxic products, see also 105, shall apply to spaces which are used for the ships' radio and main navigating equipment, cabins, mess rooms, toilets, hospitals, galleys, etc., but shall not apply to spaces not normally manned such as deck stores, forecastle stores, engine room casings, steering gear compartments, workshops. The requirement does also not apply to cargo control rooms located within the cargo area.

When internal closing is required, this shall include both ventilation intakes and outlets.

The closing devices shall give a reasonable degree of gas tightness. Ordinary steel fire-flaps without gaskets or seals will normally not be considered satisfactory.

### C 200 Hazardous spaces and cargo tanks

**201** Arrangements for cargo tanks, hold spaces and other spaces containing gas sources shall provide:

- access through horizontal openings, hatches or manholes, the dimensions of which 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 not be less than 600 mm by 600 mm
- access through vertical openings or manholes providing passage through the length and breadth of the space, the minimum clear opening of which shall not be less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom plating, unless gratings or other footholds are provided.

For the purpose of this item the following applies:

- 1) The term *minimum clear opening of not less than 600 x 600 mm* means that such openings may have corner radii up to 100 mm maximum.

#### Guidance note:

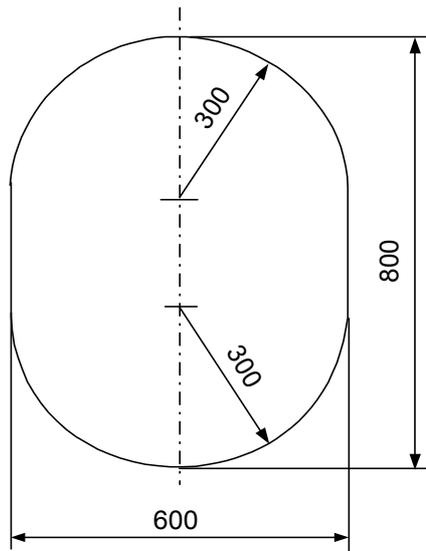
Due regard should be given to avoid high stress concentrations. Thus for areas with high stresses the radius can be increased to

$$r = 0.2 \times b \text{ (min. 600 mm), i.e. 120 mm.}$$

For definition of: b = "breadth of opening", see Pt.3 Ch.1 Sec.5 E.

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- 2) The term *minimum clear opening of not less than 600 x 800 mm* includes also an opening of the size given in Fig.2.
- 3) Circular access openings in type C cargo tanks shall have diameters of not less than 600 mm.



**Fig. 2**  
**Minimum clear opening of not less than 600 x 800 mm**

**202** The dimensions referred to in 201, may be decreased in special circumstances upon consideration.

**203** Access to cargo tanks shall be provided direct from the open deck.

**204** Arrangement of cargo pump rooms and cargo compressor rooms shall be such as to ensure safe access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. All valves necessary for cargo handling shall be accessible to personnel wearing protective clothing.

**205** The requirements of 201 do not apply to spaces separated by a single gastight steel boundary from hold spaces containing a cargo tank requiring a secondary barrier. Such spaces shall be provided only with direct or indirect access from the open weather deck, not including an enclosed non-hazardous space.

### C 300 Air locks

**301** An air lock is a space enclosed by gastight steel bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Subject to the requirements of the *International Convention on Load Line* (see Pt.3 Ch.3 Sec.6), the door sill shall not be less than 300 mm in height. The doors shall be self-closing without any holding back arrangements.

**302** Air locks shall have efficient ventilation. Ventilation requirements, see Sec.10.

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

**304** An air lock is permitted only between a gas-dangerous zone on the open weather deck and a gas-safe space except as permitted by 101.

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

**306** The air lock space shall be monitored for cargo vapour.

**307** In ships carrying flammable products, electrical equip-

ment which is not of the certified safe type in spaces protected by air-locks shall be de-energized upon loss of overpressure in the space (see also Sec.12). Electrical equipment which is not of the certified safe type for manoeuvring, anchoring and mooring equipment as well as the emergency fire pumps shall not be located in spaces to be protected by air-locks.

### C 400 Cofferdams and pipe tunnels

**401** Cofferdams shall be of sufficient size for easy access to all parts. Minimum distance between bulkheads: 600 mm.

**402** Ballast tanks will be accepted as cofferdams.

**403** Pipe tunnels shall have ample space for inspection of the pipes. The pipes shall be situated as high as possible above the ship's bottom.

**404** On ships with integral tanks, no connections between a pipe tunnel and the engine room either by pipes or manholes will be accepted.

## D. Guard Rails and Bulwarks

### D 100 Arrangement

**101** In the cargo area open guard rails are normally to be fitted. Plate bulwarks with a 230 mm high continuous opening at lower edge may be accepted upon consideration of the deck arrangement and probable gas accumulation.

## E. Diesel Engines Driving Emergency Fire Pumps or Similar Equipment

### E 100 General

**101** Diesel engines driving emergency fire pumps or similar equipment shall be installed in a non-hazardous area.

**102** The exhaust pipe of the diesel engine shall have an effective spark arrestor and shall be led out to the atmosphere at a safe distance from hazardous areas.

## F. Chain Locker and Windlass

### F 100 General

**101** The chain locker shall be arranged as a non-hazardous space. Windlass and chain pipes shall be situated in a non-hazardous area.

## G. Anodes, Washing Machines and other Fittings in Tanks and Cofferdams

### G 100 General

**101** Anodes, washing machines and other permanently installed equipment in tanks and cofferdams shall be securely fastened to the structure. The units and their supports shall be able to withstand sloshing in the tanks and vibratory loads as well as other loads which may be imposed in service.

#### Guidance note:

When selecting construction materials for permanently installed equipment in tanks and cofferdams, due consideration ought to be given to the contact spark-producing properties.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

## SECTION 4 ARRANGEMENTS AND ENVIRONMENTAL CONTROL IN HOLD SPACES

### A. General Requirements

#### A 100 Access for inspection

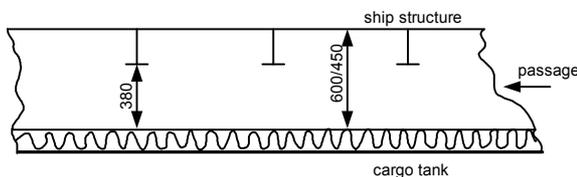
**101** Visual inspection shall be possible of at least one side of the inner hull structure without the removal of any fixed structure or fitting.

If such a visual inspection, whether combined with those inspections required in 102, B107 or Sec.14 A106 or not, is only possible at the outer surface of the inner hull, the inner hull shall not be a fuel-oil tank boundary wall.

**102** Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

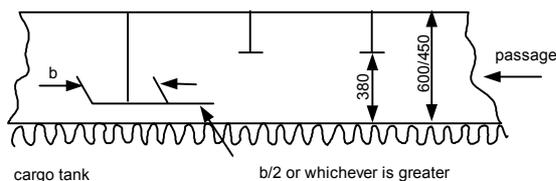
**103** Designated passage ways below and above cargo tanks shall have at least the cross sections as required by Sec.3 C201. For the purpose of 101 or 102 the following applies:

- 1) Where the surveyor requires to pass between the surface to be inspected, flat or curved, and structural elements such as deckbeams, stiffeners, frames, girders etc., the distance between that surface and the free edge of the structural elements should 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, should be at least 450 mm in case of a curved tank surface (e.g. in case of type C-tank) or 600 mm in case of a flat tank surface (e.g. in case of type A-tank). See Fig.1.



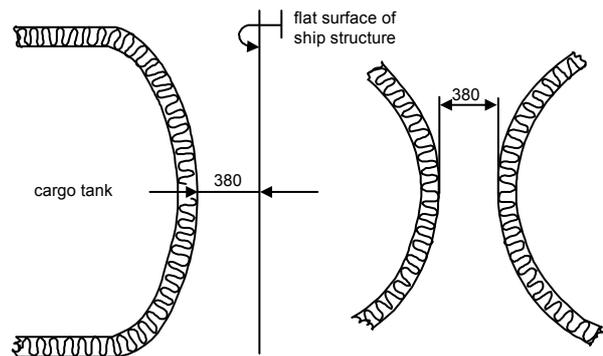
**Fig. 1**  
Minimum passage requirements involving structural elements

- 2) Where the surveyor does not require 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. See Fig.2.



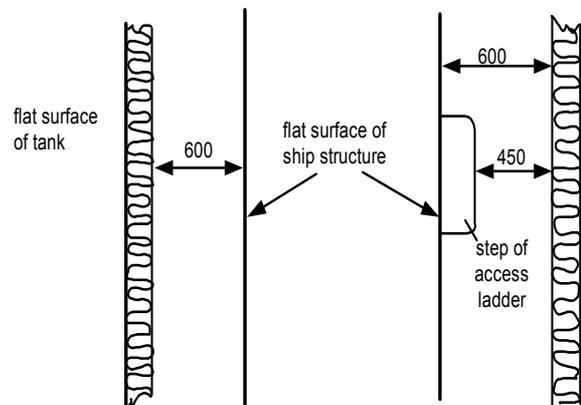
**Fig. 2**  
Minimum visibility requirements

- 3) If for inspection of a curved surface the surveyor requires 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, see Fig.3. Where the surveyor does not require 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.



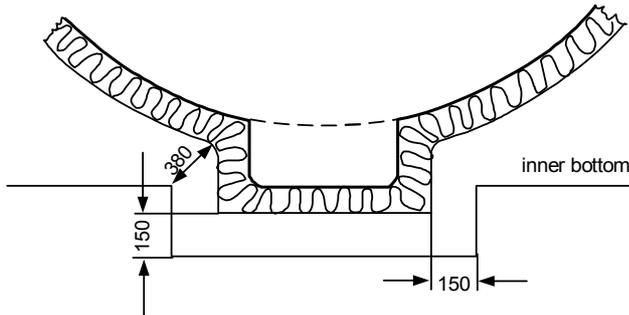
**Fig. 3**  
Minimum passage requirements between two curved surfaces

- 4) If for inspection of an approximately flat surface the surveyor requires 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, see Fig.4.



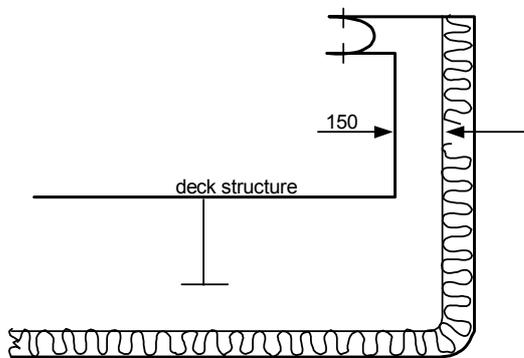
**Fig. 4**  
Minimum passage requirements between flat surfaces

- 5) The minimum distances between a cargo sump and adjacent double bottom structure in way of a suction wells shall not be less than shown in Fig.5. 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. 5**  
**Minimum distance requirements involving a cargo sump**

- 6) The distance between a cargo tank dome and deck structures shall not be less than 150 mm, see Fig.6.



**Fig. 6**  
**Minimum distance requirement between cargo tank dome and deck structures**

- 7) If necessary for inspection fixed or portable staging should be installed. This staging should not impair the distances required under 1) to 4).
- 8) If fixed or portable ventilation ducting has to be fitted in compliance with Sec.10 A400 such ducting shall not impair the distances required under 1) to 4).

## B. Secondary Barrier

### B 100 General

**101** Where the cargo temperature at atmospheric pressure is below  $-10^{\circ}\text{C}$ , a secondary barrier shall be provided when required by 103 to act as a temporary containment for any envisaged leakage of liquid cargo through the primary barrier.

**102** Where the cargo temperature at atmospheric pressure is not below  $-55^{\circ}\text{C}$ , the hull structure may act as a secondary barrier. In such a case the design shall be such that this temperature will not result in unacceptable hull stresses.

**103** Secondary barriers in relation to tank types are normally to be provided in accordance with Table B1.

Table B1 Secondary barriers in relation to tank types		
Basic tank type	Cargo temperature at atmospheric pressure	
	Below $-10^{\circ}\text{C}$ down to $-55^{\circ}\text{C}$	Below $-55^{\circ}\text{C}$
Integral tank	Hull may act as secondary barrier	Separate secondary barrier where required
Membrane tank	Tank type not normally allowed <sup>1)</sup>	
Semi-membrane tank	Complete secondary barrier	
Independent tank	Complete secondary barrier <sup>2) 3)</sup>	
- type A	Complete secondary barrier	
- type B	Partial secondary barrier <sup>3)</sup>	
- type C	No secondary barrier required	
Internal insulation	Complete secondary barrier	
- type 1	Complete secondary barrier is incorporated	
- type 2	Complete secondary barrier is incorporated	

1) A complete secondary barrier is normally required if cargoes with a temperature at atmospheric pressure below  $-10^{\circ}\text{C}$  are permitted in accordance with Sec.1 D103.

2) In the case of semi-membrane tanks which comply in all respects with the requirements applicable to independent tanks type B, except for the manner of support, the Society may, after special consideration, accept a partial secondary barrier.

3) The extent of necessary calculations and documentation will be decided in each separate case based on tank size and design.

Table B1 indicates the basic requirements with respect to secondary barrier. For tanks which differ from the basic tank types as defined in Sec.1 D, the secondary barrier requirements will be decided in each separate case.

**104** The secondary barrier shall be designed so that:

- it is capable of containing any envisaged leakage of liquid cargo for a period of at least 15 days, unless different requirements apply for particular voyages. This condition shall be fulfilled taking into account the load spectrum defined in Sec.5 A710
- it will prevent lowering of the temperature of the ship structure to an unsafe level in case of leakage of the primary barrier
- the mechanism of failure for the primary barrier does not also cause failure of the secondary barrier and vice-versa.

**105** The functions of the secondary barrier shall be ensured assuming a static angle of heel equal to  $30^{\circ}$ .

**106** Where a partial secondary barrier is required, its extent shall be determined on the basis of cargo leakage corresponding to the extent of failure resulting from the load spectrum defined in Sec.5 A710 after the initial detection of a primary barrier leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors. In all cases, however, the inner bottom in way of cargo tanks shall be protected against liquid cargo. Clear of the partial secondary barrier, provisions shall be made to deflect any liquid cargo down into the space between the primary and secondary barriers and to keep the temperature of the hull structure at a safe level (spray-shield).

**107** The secondary barrier shall be capable of being periodically checked for its effectiveness. Checking may be a pressure/vacuum test, a visual inspection or another suitable method.

### B 200 Insulation

**201** If the secondary barrier is provided by insulation, the insulation shall be liquid-tight or protected by a liquid-tight coating, so that the cargo will not come in direct contact with any

parts of the hull. The parts of the insulation situated above the liquid level need not be liquid-tight or protected by a liquid-tight coating.

**202** The insulation shall be able to withstand the loads it is exposed to under the above-mentioned conditions, without the insulation itself or the liquid-tight coating being damaged.

**203** Systems for which sufficient service experience has not been gained, shall be tested for their purpose. Experiments are normally to be carried out on an experimental tank, which is representative of conditions on board, both as regards size and construction.

### C. Gas Pressure Relief Devices

#### C 100 Pressure/vacuum valves

**101** If spaces for independent tanks may be completely closed, these spaces shall be equipped with pressure and vacuum valves. The number and size of these valves shall be decided depending on size and shape of the spaces.

**102** The valves are normally to open at pressure of 0.15 bar above and below atmospheric pressure.

#### C 200 Pressure relief hatches

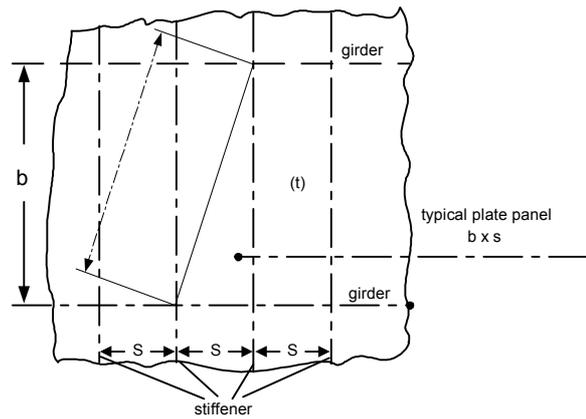
**201** If independent tanks are surrounded by a secondary barrier, the spaces between the primary and secondary barriers shall be equipped with blow-out membranes or pressure relief hatches which shall open when the pressure exceeds 0.25 bar.

**202** The combined relieving capacity of the pressure relief devices for interbarrier spaces surrounding type A independent cargo tanks where the insulation is fitted to the cargo tanks may be determined by the following formula:

$$Q_{sa} = 3.4 A_c \frac{\rho}{\rho_v} \sqrt{h} \quad (\text{m}^3/\text{s})$$

- $Q_{sa}$  = minimum required discharge rate of air at standard conditions of 273 K and 1.013 bar
- $A_c$  = design crack opening area ( $\text{m}^2$ )
- $A_c$  =  $\frac{\pi}{4} \delta l$  ( $\text{m}^2$ )
- $\delta$  = maximum crack opening width (m)
- $\delta$  = 0.2 t (m)
- t = thickness of tank bottom plating (m)
- l = design crack length (m) equal to the diagonal of the largest plate panel of the tank bottom, see Fig. 7
- h = maximum liquid height above tank bottom plus 10 x MARVS (m)
- $\rho$  = density of product liquid phase ( $\text{kg}/\text{m}^3$ ) at the set pressure of the interbarrier space relief device
- $\rho_v$  = density of product vapour phase ( $\text{kg}/\text{m}^3$ ) at the set pressure of the interbarrier space relief device and a temperature of 273 K
- MARVS = maximum allowable relief valve setting of the cargo tank (bar)

Pressure relief devices for interbarrier spaces need not be arranged to comply with the requirements of Sec.9 B208.



**Fig. 7**  
Design crack length, l

**203** The relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type B cargo tanks shall be determined on the basis of the leakage rate determined in accordance with B106.

**204** The relieving capacity of pressure relief devices for interbarrier spaces of membrane and semi-membrane tanks shall be evaluated on the basis of the specific membrane or semi-membrane tank design.

**205** The pressure relief hatches shall be constructed to avoid risk of damage by expected external forces.

### D. Environmental Control within the Hold Space

#### D 100 Cargo containment systems requiring a secondary barrier

**101** Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full secondary barriers, shall be inerted with a suitable dry inert gas and maintained inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage which shall be sufficient for normal consumption for at least thirty days.

**102** Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring partial secondary barriers, shall be inerted with suitable, dry inert gas and maintained inerted with make-up gas provided by a shipboard inert gas generation system or by shipboard storage which shall be sufficient for normal consumption for at least thirty days, alternatively, except as limited by Sec.15, the spaces referred to in this item may be allowed to be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensure that any leakage from the cargo tank will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

**103** For non-flammable gases, the spaces referred to in 101 and 102 may be maintained with a suitable dry air or dry inert atmosphere.

**104** In case of internal insulation tanks, environmental control arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or in-

dependent tank structures completely filled with insulation material complying with Sec.7 C203.

**D 200 Cargo containment systems not requiring a secondary barrier**

**201** Spaces surrounding refrigerated cargo tanks not having secondary barriers shall be filled with suitable dry inert gas or dry air and be maintained in this condition with make-up inert gas provided by a shipboard inert gas generation system, shipboard storage of inert gas, or dry air provided by suitable air drying equipment.

**E. Sealing around Tanks**

**E 100 General**

**101** Efficient sealing shall be provided where independent tanks extend above the upper deck. The sealing material shall be such that it will not deteriorate, even at considerable movements between the tanks and the deck. The sealing shall be able to withstand all temperatures and environmental hazards which may be expected.

**F. Earth Connections**

**F 100 General**

**101** At least two effective earth connections between each tank and the hull shall be arranged.

## SECTION 5 SCANTLINGS AND TESTING OF CARGO TANKS

### A. General

#### A 100 Introduction

**101** In this section, requirements are given for scantlings and testing of cargo tanks of types as defined in Sec.1 D, together with their supporting and keying structure.

#### A 200 Approval of works

**201** Builders of cargo tanks intended for **Tanker for Liquefied Gas**, shall be especially approved by the Society for manufacturing of the type of tank in question.

#### A 300 Definitions

**301** The following definitions will normally not be repeated throughout this section:

$p_0$	= design vapour pressure as defined in Sec.1 B114 (bar)
MARVS	= the maximum allowable relief valve setting of a cargo tank (bar)
L	= ship length as given in Pt.3 Ch.1 Sec.1 (m)
$L_1$	= L, maximum 300 m
B	= greatest moulded breadth (m)
$C_B$	= block coefficient
V	= service speed (knots)
GM	= metacentric height (m)
$g_0$	= acceleration due to gravity ( $m/s^2$ )
E	= modulus of elasticity ( $N/mm^2$ )
$\rho$	= density of cargo ( $kg/m^3$ )
$\sigma_B$	= the specified minimum tensile strength at room temperature ( $N/mm^2$ ). For welded connections in aluminium alloys the tensile strength in annealed condition shall be used
$\sigma_F$	= the specified minimum upper yield stress at room temperature ( $N/mm^2$ ). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies
$\sigma_{0.2}$	= the specified minimum 0.2% proof stress at room temperature ( $N/mm^2$ ). For welded connections in aluminium alloys the 0.2% proof stress in annealed condition shall be used.

**302** *Cargo tank types* are defined in Sec.1 D.

**303** *Supporting structure* transfers forces from the keys to the main elements of the ship's hull (e.g. to the ship side and transverse bulkheads). The supporting structures may include parts of the hull structure (e.g. double bottom structures).

**304** *Keys* prevent the cargo tank from bodily movement, and form the boundary between the cargo tank and the supporting structure.

#### A 400 Design stress

**401** When determining the design stresses (as specified in this section for each type of tank), the minimum specified mechanical properties of the material, including the weld metal in the fabricated condition shall be used. For certain materials, subject to special consideration by the Society, advantage may be taken of enhanced yield strength and tensile strength at design temperatures below  $-105^\circ C$ .

#### A 500 Loads to be considered

**501** Tanks together with their supports and other fixtures shall be designed taking into account proper combinations of the various loads listed below:

— internal pressure

- external pressure
- dynamic loads due to the motion of the ship
- thermal loads
- sloshing loads
- loads corresponding to ship deflection
- tank and cargo weight with the corresponding reactions in way of supports
- insulation mass
- loads in way of towers and other attachments
- vibrations.

The extent to which these loads shall be considered depends on the type of tank, and is more fully detailed below.

#### A 600 Static loads

The following static loads shall be taken into consideration:

**601** The design vapour pressure  $p_0$  shall not be taken less than:

- 1) For cargo tanks where there is no temperature control and where the pressure of the cargo is only dictated by the ambient temperature,  $p_0$  shall not be less than the vapour pressure of the cargo at a temperature of  $45^\circ C$ . However, lesser values of this temperature may be accepted for ships operating in restricted areas or on voyages of restricted duration, and account may be taken in such cases of any insulation of the tanks. On the other hand, higher values of this temperature may be required for ships permanently operating in areas of high ambient temperatures. Moreover,  $p_0$  shall not be less than the maximum allowable relief valve setting (MARVS).
- 2) The pressure of the inert gas for tanks unloaded by means of inert gas.

Subject to special consideration a vapour pressure higher than  $p_0$  may be accepted in harbour condition where dynamic loads are reduced, if this higher pressure is taken into account when determining the scantlings of the upper parts of the tank. However, this pressure shall not be higher than the limiting values given in Sec.1 D for the various types of tanks.

For particular cargoes as indicated in the *List of Cargoes*, special requirements to  $p_0$  may be given.

**602** The static load due to 98% filling by volume of the tank with a cargo of design density.

**603** The design external pressure,  $p_{ed}$ , shall be based on the difference between the minimum internal pressure (maximum vacuum) and the maximum external pressure to which the tank may be subjected simultaneously.

The design external pressure shall be based on the following formula:

$$p_{ed} = p_1 + p_2 + p_3 + p_4$$

- |       |   |
|-------|---|
| $p_1$ | = opening pressure of the vacuum relief valves. For tanks not fitted with vacuum relief valves, $p_1$ shall be specially considered, but is in general not to be taken less than 0.25 bar |
| $p_2$ | = for tanks or part of tanks in completely closed spaces: the set pressure of the pressure relief valves for these spaces<br>elsewhere $p_2 = 0$  |
| $p_3$ | = external head of water for tanks or part of tanks on exposed decks<br>elsewhere $p_3 = 0$   |

$p_3$  may be calculated using the formulae given in Sec.5 E303 multiplied by the factor  $c$  given in Pt.3 Ch.1 Sec.10 C100

$p_4$  = compressive actions in the shell due to the weight and contraction of 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 pressure or both should be taken into account

**604** Static forces imposed on the tank from deflection of the hull.

**605** Account shall be taken of the loads corresponding to the pressure test mentioned in N.

### A 700 Dynamic loads

**701** The determination of dynamic loads shall take account of the long term distribution of ship motions that the ship will experience during her operating life. The operating life is normally taken to correspond to  $10^8$  wave encounters on the North Atlantic. Any pertinent effects on surge, sway, heave, roll, pitch and yaw in irregular seas shall be considered.

The probability of occurrence of different ship-to-wave heading angles shall be considered, normally a uniform probability may be assumed.

The effects of speed reduction in heavy weather may be allowed for.

The wave-induced loads shall be determined according to accepted theories, model tests or full scale measurements.

**702** Ships for restricted service will be given special consideration.

**703** The accelerations acting on tanks are estimated at their centre of gravity and include the following components:

- vertical acceleration:
  - motion acceleration of heave, pitch and, possible, roll (normal to the ship base).
- transverse acceleration:
  - motion acceleration of sway, yaw and roll
  - gravity component of roll.
- longitudinal acceleration:
  - motion acceleration of surge and pitch
  - gravity component of pitch.

**704** For independent tanks type A and C, the following design accelerations shall be used unless other values are justified by independent calculations.

— vertical acceleration:

$$a_z = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L}\right)^2 \left(\frac{x}{L} + 0.05\right)^2 \left(\frac{0.6}{C_B}\right)^3}$$

— transverse acceleration:

$$a_y = \pm a_0 \sqrt{0.6 + 2.5 \left(\frac{x}{L} + 0.05\right)^2 + \kappa \left(1 + 0.6 \frac{\kappa z}{B}\right)^2}$$

— longitudinal acceleration:

$$a_x = \pm a_0 \sqrt{0.06 + A^2 - 0.25 A}$$

$$A = \left(0.7 - \frac{L}{1200} + 5 \frac{z}{L}\right) \left(\frac{0.6}{C_B}\right)$$

$x$  = longitudinal distance from amidships to centre of gravity of the tank with content (m).  $x$  is positive forward of amidships, negative aft of amidships

$z$  = vertical distance from the ship's actual waterline to the centre of gravity of tank with content (m).  $z$  is positive above and negative below the waterline

$$a_0 = \frac{0.2V}{\sqrt{L}} + \frac{34 - \frac{600}{L}}{L}$$

$V$  = service speed (knots)

Generally,  $\kappa = 1.0$ . For particular loading conditions and hull forms, determination of  $\kappa$  according to the formula below may be necessary.

$$\kappa = \frac{13GM}{B} \quad (\kappa \geq 1.0, GM = \text{metacentric height (m)})$$

$a_x$ ,  $a_y$  and  $a_z$  are the maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions and may be assumed to act independently.

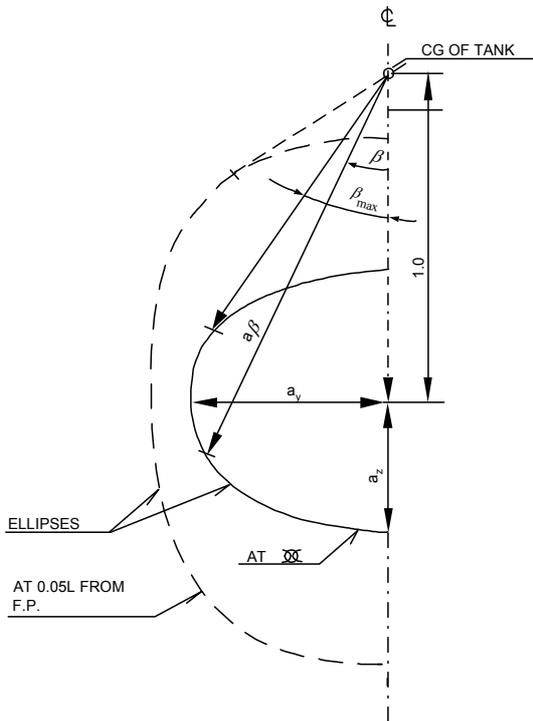
$a_z$  does not include the component of the static mass.

$a_y$  includes the component of the static mass in the transverse direction due to rolling.

$a_x$  includes the component of the static mass in the longitudinal direction due to pitching.

Speed reduction in heavy weather has been taken into account in these formulae.

The most probable acceleration  $a_\beta$  in a given direction  $\beta$  may be found as shown in Fig.1. Where acceleration in three directions need to be considered, an ellipsoid shall be used instead of the ellipse.



**Fig. 1**  
Resulting acceleration (static + dynamic)  $a_\beta$  in arbitrary direction  $\beta$ .

**705** The following formula gives the value of internal pressure (or design liquid pressure) in a full tank, resulting from the design vapour pressure  $p_0$  and the liquid pressure defined in 706, but not including effects of liquid sloshing.

$$p_{eq} = p_0 + (p_{gd})_{max} \text{ (bar)}$$

Equivalent procedures may be applied.

**706** 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. The following formula gives the value of internal liquid pressure, resulting from combined effects of gravity and dynamic acceleration:

$$p_{gd} = \frac{a_\beta Z_\beta \rho}{1.02 \cdot 10^4} \text{ (bar)}$$

$a_\beta$  = the dimensionless acceleration (i.e. relative to the acceleration of gravity) resulting from gravitational and dynamic loads, in an arbitrary direction  $\beta$  (see Fig.1)

$\rho$  = the maximum density of the cargo in  $\text{kg/m}^3$  at the design temperature

$Z_\beta$  = largest liquid height (m) above the point where the pressure shall be determined measured from the tank shell in the  $\beta$  direction (see Fig.2)

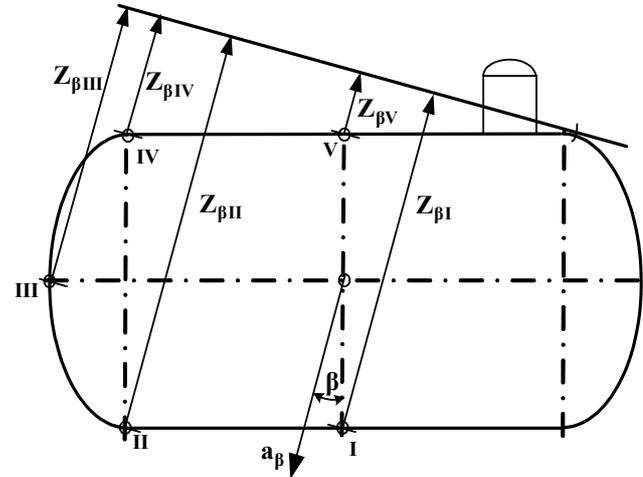
Tank domes considered to be part of the accepted total volume should be taken into account when determining  $Z_\beta$  unless the total volume of tank domes  $V_D$  does not exceed the following value:

$$V_D = V_T \left( \frac{100 - FL}{FL} \right) (\text{m}^3)$$

$V_T$  = tank volume without any domes ( $\text{m}^3$ )

FL = Filling limit according to Sec.17 A101 or 103 in %.

The direction  $\beta$  which gives the maximum value  $(p_{gd})_{max}$  of  $p_{gd}$ , shall be considered. Where accelerations in three directions need to be considered, an ellipsoid shall be used instead of the ellipse in Fig.1.



**Fig. 2**  
Liquid heights,  $Z_\beta$ , for check points I-V, in the  $\beta$ -direction.

**707** When detailed studies of wave induced loads are required as usually for membrane tanks, semi-membrane tanks and independent tanks type B, the loads given in 708, 709 and 710 shall be used.

**708** For design against plastic deformations and buckling, the loads are normally to be taken as the most probable largest loads in  $10^8$  wave encounters (probability level  $Q = 10^{-8}$ ) for a ship operating on the North Atlantic.

All types of wave-induced loads and motions exerted by the hull and the cargo on the tank structure shall be considered.

Generally, these types of loads are:

- vertical, transverse and longitudinal acceleration forces
- internal liquid pressure in the tank (full and partially full)
- external water pressure on the hull
- vertical and horizontal bending of the hull girder
- torsion of the hull girder.

**709** For design against fatigue the load spectrum is normally to be taken as the most probable largest load spectrum the ship will experience during  $10^8$  wave encounters on the North Atlantic.

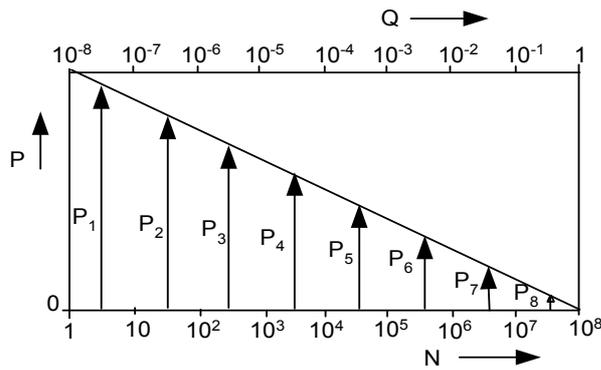
Generally, the load spectrum shown in Fig.3 may be used. This load spectrum may be replaced by a number of 8 fatigue loads, each of which is represented by a certain number of cycles,  $n_i$ , and an alternating load  $\pm P_i$ . Corresponding values of  $P_i$  and  $n_i$  are given by:

$$P_i = \frac{17 - 2i}{16} P_0$$

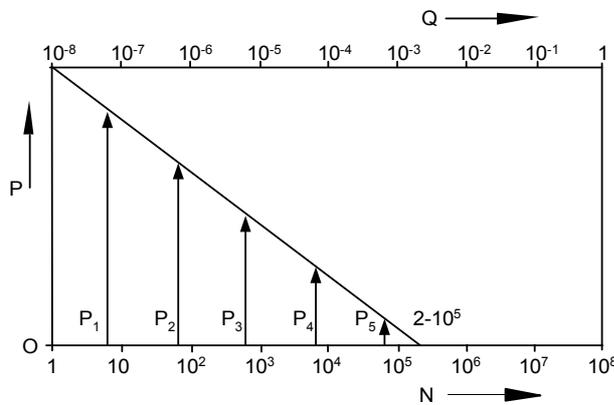
$$n_i = 0.9 \cdot 10^i$$

$i = 1, 2, 3, 4, 5, 6, 7, 8$

$P_0$  = load on probability level  $Q = 10^{-8}$



**Fig. 3**  
**Long term wave-induced load spectrum**



**Fig. 4**  
**Load spectrum representing the worst period of 15 days in the long term induced load spectrum**

**710** For design against crack propagation the load spectrum is normally to be taken as the load spectrum representing the worst period of 15 days in the most probable largest load spectrum the ship will experience during  $10^8$  wave encounters on the North Atlantic.

Generally the load spectrum shown in Fig.4 may be used. This load spectrum may be replaced by a number of 5 fatigue loads, each of which is represented by a certain number of cycles,  $n_i$ , and an alternating load  $\pm P_i$ . Corresponding values of  $P_i$  and  $n_i$  are given by:

$$P_i = \frac{5.5 - i}{5.3} P_0$$

$$n_i = 1.8 \cdot 10^i$$

$i = 1, 2, 3, 4, 5$

$P_0 =$  load on probability level  $Q = 10^{-8}$ .

**A 800 Sloshing loads**

**801** When partial tank filling is contemplated, the risk of significant loads due to sloshing induced by any of the ship motions mentioned in 703, shall be considered.

**802** When risk of significant sloshing induced loads is found to be present, special tests and or calculations will be required.

**Guidance note:**

For membrane cargo tanks reference is made to Classification Note 30.9; Sloshing analysis of LNG membrane tanks.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

**A 900 Thermal loads**

**901** Transient thermal loads during cooling-down periods shall be considered for tanks intended for cargoes with a boiling point below  $-55^\circ\text{C}$ .

**902** Stationary thermal loads shall be considered for tanks where design, supporting arrangement and operating temperature may give rise to significant thermal stresses.

**A 1000 Vibration**

**1001** Design of hull and cargo tanks, choice of machinery and propellers shall be aimed at keeping vibration exciting forces and vibratory stresses low. Calculations or other appropriate information pertaining to the excitation forces from machinery and propellers, may be required for membrane tanks, semi-membrane tanks and independent tanks type B, and in special cases, for independent tanks type A and C. Full-scale measurements of vibratory stresses and or frequencies may be required.

**A 1100 Supports**

**1101** Cargo tanks shall be supported by the hull in a manner which will prevent bodily movement of the tank under static and dynamic loads while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and of the hull.

**1102** The supports shall be calculated for the most probable largest severe resulting acceleration taking into account rotational as well as translational effects. This acceleration in a given direction  $\beta$  may be determined as shown in Fig.1. The half axes of the "acceleration ellipse" are determined according to 704.

**1103** For independent tanks and, where appropriate, for membrane and semi-membrane tanks, provisions shall be made to key the tanks against the rotational effects referred to in 1102.

**1104** The tanks with supports shall be designed for a static inclination of  $30^\circ$  without exceeding the allowable stresses specified for the various types of tanks.

**1105** Suitable supports shall be provided to withstand a collision force acting on the tank corresponding to one half the weight of the tank and cargo in the forward direction and one quarter the weight of the tank and cargo in the aft direction without deformation likely to endanger the tank structure.

**1106** The loads mentioned in 1104 and 1105 need not be combined with each other or with wave-induced loads.

**1107** Antifloatation arrangements shall be provided for independent tanks. The antifloatation arrangements shall be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the load draught of the ship, without plastic deformation likely to endanger the hull structure.

**A 1200 Corrosion allowance**

**1201** For independent tanks no corrosion allowance is generally required if the contents of the tank are non-corrosive and the external surface is protected by inert atmosphere or by an appropriate insulation with an approved vapour barrier. Paint or other thin coatings exposed to weather or mechanical damage will not be credited as external protection. Where austenitic stainless steel, aluminium alloys and other special alloys are used with acceptable corrosion resistance, no corrosion allowance will in general be required. If the above conditions are not satisfied, the scantlings calculated according to subsections E, F, G, H and I shall be increased as appropriate.

**1202** For integral tanks the corrosion allowance is in general to be in accordance with Pt.3 Ch.1 Sec.2 D. However, if the cargo is non-corrosive, no corrosion allowance will be required on the internal surface.

### A 1300 Fracture mechanics analysis

**1301** An analysis according to 1302 shall be carried out for independent tanks type B, and may be required in special cases, for semi-membrane tanks.

**1302** A fatigue crack propagation analysis shall be carried out for areas with high dynamic stresses. The analysis shall consider propagation rates in parent material, weld metal and heat-affected zone.

The analysis shall establish the size and shape of possible fatigue cracks at penetration of the tank wall, taking into account the stress distribution through the tank wall. The largest crack dimension at penetration is defined as  $a_i$ .

The crack dimension,  $a_d$ , to which  $a_i$  will extend under dynamic loading before detection by gas leakage is possible, shall be documented. Further, the length  $a_f$  to which this crack  $a_d$  will grow under dynamic loading based on a stress spectrum corresponding to the worst period of 15 days in the long term spectrum as given in 710, shall be determined.

The permissible length of  $a_f$  shall be considered by the Society in each separate case, and shall be considerably less than the critical crack size  $a_c$ .

If necessary, the above requirements to establishment of critical crack sizes and fatigue crack sizes and shapes may have to be documented by means of experiments. The fracture toughness properties of the tank material and its welded joints in the thicknesses used in the design, shall be well documented to permit determination of the critical crack sizes or conservative estimates of critical crack sizes for important parts of the tanks. The determination of critical crack sizes,  $a_c$ , shall be performed using recognised calculation procedures which have to be approved in each case.

The fracture toughness properties shall be expressed using recognised standards or practice e.g., ASTM E 399 (latest issue) or BS 7448 (latest issue).

Depending on material, fracture toughness properties determined for loading rates similar to those expected in the tank system may be required.

The fatigue crack propagation rate properties shall be documented for the tank material and its welded joints for the relevant service conditions. These properties shall be expressed using a recognised fracture mechanics practice relating the fatigue crack propagation rate to the variation in stress intensity ( $\Delta K$ ) at the crack tip. The effect of stresses produced by static loads as given in 600 shall be taken into account when establishing the choice of fatigue crack propagation rate parameters.

### A 1400 Fatigue analysis

**1401** An analysis according to 1402 and 1403 shall be carried out for independent tanks type B and may, in special cases, be required for independent tanks type C and semi-membrane tanks.

**1402** A fatigue analysis shall be carried out for parent material and welded connections at areas where high dynamic stresses or large stress concentrations may be expected.

The fatigue properties shall be well documented for the parent material and welded connections being used in the design. For less investigated and documented materials, the data on fatigue properties shall be determined experimentally. Due attention shall be paid to the effect of:

- specimen size and orientation
- stress concentration and notch sensitivity
- type of stress
- mean stress
- type of weld
- welding condition
- working temperature.

The number of specimens to be tested at each stress level shall not be less than 6.

The fatigue strength of the structure considered shall be illustrated by Wöhler curves (S-N curves).

**1403** The fatigue analysis shall be based on the fatigue loading given in 709. The number of complete stress cycles due to loading and unloading is in general to be 1000. The cumulative effect of the various fatigue loads shall satisfy the following requirement:

$$0.9 \sum_{i=1}^{i=8} \left( \frac{10^i}{N_i} \right) + \frac{10^3}{N_9} < C_W$$

$N_i$  = number of cycles to fracture for wave-induced fatigue load number  $i$ , according to Wöhler curves

$N_9$  = number of cycles to fracture for the fatigue load due to loading and unloading

The effect of stresses produced by static load as given in 600 shall be taken into account.

$C_W \leq 0.5$ . Subject to special consideration a value greater than 0.5 but not greater than 1.0 may be used, dependent on the test procedure and data used to establish the Wöhler curve (S-N curve).

## B. Integral Tanks

### B 100 General

**101** Reference is made to Pt.3.

**102** Tanks for cargoes with density below 1 000 kg/m<sup>3</sup> shall have scantlings at least as tanks constructed for liquid cargoes with density equal to that of seawater.

**103** Tanks for cargoes with density above 1 000 kg/m<sup>3</sup>, see Pt.3 Ch.1 Sec.4 C.

**104** For materials other than mild steel, the minimum thickness requirements will be considered in each case.

## C. Membrane Tanks

### C 100 General

**101** For membrane tanks, the effects of all static and dynamic loads shall be considered to determine the suitability of the membrane and of the associated insulation with respect to plastic deformation and fatigue.

**102** Before approval is granted, a model of both the primary and secondary barrier, including corners and joints, is normally to be tested to verify that it will withstand the expected combined strains due to static, dynamic and thermal loads. Test conditions shall represent the most extreme service conditions the tank will see in its life. Material tests shall ensure that ageing is not liable to prevent the materials from carrying out their intended function.

**103** For the purpose of the test referred to in 102, a complete analysis of the particular motions, accelerations and response of ships and tanks shall be performed according to A700, as applicable, unless these data are available from similar ships.

**104** Special attention shall be paid to the possible collapsing of the membrane due to an overpressure in the interbarrier space, to a possible vacuum in the tanks, to the sloshing effects and to hull vibration effects.

**105** The structural analysis of the hull shall be performed in accordance with the rules for hull structure given in Pt.3. Special attention is, however, to be paid to deflections of the hull

and their compatibility with the membrane and associated insulation.

**Guidance note:**

Methods for strength analysis of hull structure in liquefied gas carriers with membrane tanks are given in Classification Note No. 31.9.

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**106** The allowable stresses for the membrane, membrane supporting material and insulation will be determined in each particular case.

**107** It shall be possible by means of a dependable and efficient method to control that the primary or the secondary barrier is free from small leakages, which may be difficult to detect by visual inspection. A description of the proposed leakage detection method shall be submitted for consideration.

## D. Semi-Membrane Tanks

### D 100 General

**101** Structural analysis shall be performed in accordance with the requirements for membrane tanks or independent tanks, as appropriate, taking into account the internal pressure as indicated in A705 and A706.

## E. Independent Tanks Type A

### E 100 Tanks constructed mainly of plane surfaces

**101** Independent tanks type A, primarily constructed of plane surfaces (gravity tanks), shall be designed according to 200 and 300.

### E 200 Tank shell plating and stiffeners

**201** The thickness requirement for the tank shell plating corresponding to lateral pressure is given by:

$$t = \frac{15.8s\sqrt{p}}{\sqrt{215 f_1}} \quad (\text{mm})$$

p = pressure as given in A705 (kN/m<sup>2</sup>) (1 bar = 100 kN/m<sup>2</sup>)  
s = stiffener spacing measured along the plating (m)

t shall not be taken less than 10 s mm but not less than 8.0 mm.

**202** The section modulus requirement for simple stiffeners is given by:

$$Z = \frac{1000 l^2 s p}{m \sigma} \quad (\text{cm}^3)$$

p = pressure as given in A705 (kN/m<sup>2</sup>) (1 bar = 100 kN/m<sup>2</sup>)  
l = stiffener span (m)  
s = stiffener spacing measured along the plating (m)  
σ = stress in N/mm<sup>2</sup> taken as the lower of σ<sub>B</sub>/2.66 and σ<sub>0.2</sub>/1.33.

m-values normally to be applied:

m = 7.5 for vertical stiffeners simply supported at one or both ends  
= 10 for transverse stiffeners and vertical stiffeners which may be considered fixed at both ends  
= 12 for longitudinal stiffeners which may be considered fixed at both ends.

The m-value may be adjusted for members with boundary condition not corresponding to the above specification or a direct

calculation including the supporting boundary structure may be done, see Pt.3 Ch.1 Sec.12.

**203** Stiffeners supported by end bulkheads or swash bulkheads or stringers subject to relatively large deflections shall be checked by direct stress calculation using allowable stress of 160 f<sub>1</sub> N/mm<sup>2</sup> in the static loads and 215 f<sub>1</sub> N/mm<sup>2</sup> in the condition with static and dynamic loads.

**204** Connection area of stiffeners shall be according to Pt.3 Ch.1 Sec.12 C400. The design pressure load p may then be taken according to A705 and A706, applying half values for a<sub>x</sub>, a<sub>y</sub> and a<sub>z</sub> in the calculation of a<sub>β</sub>.

**205** The web and flange thickness shall not be less than the larger of:

$$t = 5.0 + \frac{k}{\sqrt{f_1}}$$

$$t = \frac{h}{g}$$

k = 0.02 L<sub>1</sub> (= 5.0 maximum)

h = profile height (mm)

g = 70 for flanged profile

g = 20 for flat bar profiles.

**206** The sloshing load on wash bulkheads shall be according to Pt.3 Ch.1 Sec.4 C300. The requirement for structures should be as given in Pt.3 Ch.1 Sec.9.

### E 300 Girder systems

**301** For webs, girders and stringers, a structural analysis shall be carried out to ensure that the stresses are acceptable. Calculation methods applied shall take into account the effects of bending, shear, axial and torsional deformations as well as the hull cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottom.

**302** The following loads and stresses shall be taken into consideration:

- static loads according to A600
- dynamic additional loads due to the ship's movement in a seaway. See 303 to 305 and A704 to A706
- thermal stresses.

**303** The dynamic, additional, external water pressure on the ship's hull shall be taken as:

- For load points below the summer load waterline:

$$p_{ed} = 2 p_{dp}$$

- For load points above the summer load waterline:

$$p_{ed} = 2 p_2$$

p<sub>dp</sub> and p<sub>2</sub> = dynamic pressure as given in Pt.3 Ch.1 Sec.4.

L<sub>1</sub> = L, maximum 300 m.

**304** If a tank may be partly filled, dynamic forces due to liquid movement shall be taken into consideration as given in Pt.3 Ch.1 Sec.4 C303 to C310.

**305** The vertical load on the supporting structure is given by:

$$P_z = (1 + a_z) M g_0 \quad (\text{kN})$$

a<sub>z</sub> = vertical acceleration

M = mass of tank and content in t.

The load on keys designed to take transverse forces is given by:

$$P_y = a_y M g_0 \quad (\text{kN})$$

a<sub>y</sub> = transverse acceleration.

The point of attack of the force is at the tank's centre of gravity.

The load on keys designed to take longitudinal forces is given by:

$$P_x = a_x M g_0 \quad (\text{kN})$$

$a_x$  = longitudinal acceleration.

The point of attack of the force is at the tank's centre of gravity.

Formulae for the accelerations  $a_x$ ,  $a_y$  and  $a_z$  are given in A704. For static inclination and longitudinal collision load, see A1104, 1105 and 1106.

**306** For the main structure of the tank (webs, stringers and girders) as well as the supporting and keying structure, the allowable nominal stresses, when the tanks are loaded as described in 301 to 305, are given below:

Static load:

$\sigma_e$  shall not exceed  $150 f_1 \text{ N/mm}^2$

$\tau_m$  shall not exceed  $80 f_1 \text{ N/mm}^2$

Static and dynamic load:

$\sigma_e$  shall not exceed  $215 f_1 \text{ N/mm}^2$

$\tau_m$  shall not exceed  $115 f_1 \text{ N/mm}^2$

$\tau_m$  = mean shear stress over a net cross section

$\sigma_e$  = equivalent stress defined in Pt.3 Ch.1 Sec.13

$f_1$  = material factor as given in Pt.3 Ch.1 Sec.2.

For tanks supported in such a way that the deflections of the hull affects significantly the stresses of the tank, that part of the hull structure which supports the tank shall be defined as supporting structure and dimensioned accordingly.

The criteria given in this paragraph and 308 are applicable to cargo tank structures and double bottom structures loaded by a cargo tank filled with liquefied gas.

For load cases considered in A500 where one or more cargo tanks are empty, the supporting structure in way of empty cargo tanks may generally be dimensioned using loads according to Pt.3 Ch.1 Sec.4 and strength criteria according to Pt.3 Ch.1 Sec.13 and Pt.3 Ch.1 Sec.14.

**Guidance note:**

For independent tanks type A, with tank supports distributed on the inner bottom, the whole double bottom may, depending on the load case considered, be regarded as supporting structure.

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**307** The stiffening of webs, stringers and girders shall be in accordance with the requirements given in Pt.3 Ch.1 Sec.3.

The web and flange thickness shall not be less than:

$$t = 5.0 + \frac{k}{\sqrt{f_1}}$$

$k = 0.02 L_1$  (= 5.0 maximum)

**308** A complete stability analysis of plates, stiffeners and girders defined in 306 shall be submitted when deemed necessary by the Society. Buckling control shall be carried out according to Pt.3 Ch.1 Sec.14, but with the following usage factors when the local load, or local and global load shall  $10^{-8}$  probability level:

- for plates in uniaxial compression  $\eta = 0.95$
- for stiffeners  $\eta = 0.90$
- for plates in biaxial compression  $\eta_x, \eta_y = 1.0$

**E 400 Tanks constructed mainly of bodies of revolution**

**401** Independent tanks type A, constructed primarily of bodies of revolution, will be dealt with in each individual case, but the requirements given for independent tanks type C with respect to internal pressure, buckling and stresses in way of supports, are in general applicable.

**F. Independent Tanks Type B**

**F 100 General**

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

- plastic deformation
- buckling
- fatigue failure
- crack propagation and brittle fracture.

**102** A complete analysis of the particular ship accelerations and motions in irregular waves according to A700 and of the response of ship and tanks to these forces and motions shall be performed, unless these data are available from similar ships.

**103** The structural analysis shall be carried out using analytical tools such as:

- finite element analysis
- shell theory
- frame work analysis (beam theory), when appropriate.

**104** For the evaluation of the overall structural response of the tank, a 3-dimensional analysis shall be carried out. The model shall include the cargo tank with its supporting and keying systems as well as a reasonable part of the hull.

**105** When performing the structural analysis of the various parts forming the cargo tank, appropriate models shall be used.

**106** Buckling analysis shall take into account the loads mentioned in A603 and A708, and other miscellaneous compressive loads to which the tank 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 deflections. Acceptable buckling calculation procedures for spherical cargo tank containment systems are given in Classification Note 30.3.

**107** Buckling analysis shall consider the maximum construction tolerances.

**108** For design against brittle fracture, a fracture mechanics analysis according to A1300 is required.

**109** For design against fatigue failure, a fatigue analysis according to A1400 is required.

**110** Model tests may be required to determine stress concentration factors and fatigue life of structural elements.

**111** A vibration analysis shall be carried out for the various structural components of the tank in order to obtain the natural frequencies for the significant modes of vibration.

Due attention shall be given to the effect of liquid, rotational restraint, flange stiffness and cut-outs on the natural frequencies.

**Guidance note:**

The natural frequencies for the significant modes of vibration of a structural component should comply with the following requirements:

Motor-driven ships:  $f\Delta \geq 1.1 F$

Turbine-driven ships:  $f\Delta \geq 1.1 F$  or  $f\Delta \leq 0.55 F$

$f$  = natural frequency for the actual mode of vibration in air (Hz.)

$\Delta$  = reduction factor for the natural frequency when the structural component is immersed in liquid

F = highest local excitation frequency expected to be of significance plus 10% (Hz.)

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**112** Post-weld heat treatment may be required for parts of tanks dependent on construction, material thickness and type of material used.

**113** Only plus-tolerances are allowed on the design wall thickness.

### F 200 Equivalent stress and summation of static and dynamic stresses

**201** The equivalent stress shall be calculated according to the formula:

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

$\sigma_x$  = total normal stress in x-direction  
 $\sigma_y$  = total normal stress in y-direction  
 $\tau_{xy}$  = total shear stress in the x-y plane.

The method to be used for determining  $\sigma_x$ ,  $\sigma_y$  and  $\tau_{xy}$ , shall be considered in each separate case. In special cases the methods given in the Guidances below may be used.

#### Guidance note:

Total stresses in given directions in any point of a structure may be calculated according to the following formulae:

$$\sigma_x = \sigma_{xs} \pm \sqrt{\Sigma(\sigma_{xdn})^2}$$

$$\sigma_y = \sigma_{ys} \pm \sqrt{\Sigma(\sigma_{ydn})^2}$$

$$\tau_{xy} = \tau_{xys} \pm \sqrt{\Sigma(\tau_{xydn})^2}$$

$\sigma_{xs}$ ,  $\sigma_{ys}$  and  $\tau_{xys}$  are static stresses.

$\sigma_{xdn}$ ,  $\sigma_{ydn}$  and  $\tau_{xydn}$  are dynamic component stresses determined separately from acceleration components and hull strain components due to deflection and torsion.

Coupling effects shall be considered if the dynamic component stresses in a given direction may not be assumed to act independently.

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#### Guidance note:

Total stresses in given directions in any point of the structure may be determined directly by considering the ship in dynamic equilibrium. By this method, the instantaneous response of the structure considered is determined for the ship moving in a design wave. The design wave is determined by comparing the transfer function for a given wave length with the long term distribution value, thus obtaining a design wave height. This wave height is used as a magnifying factor for all loads. The wave length which gives the worst combination of the most important loads shall be used.

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## G. Independent Tanks Type B, Primarily Constructed of Bodies of Revolution

### G 100 Terms used for stress analysis

**101** Terms used for stress analysis are defined in 102 to 110. Stress categories and stress limits are given in 302 to 306.

**102** *Normal stress* - the component of the stress normal to the section of reference.

**103** *Membrane stress* - the component of a normal stress which is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

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

**105** *Shear stress* - the component of the stress acting in the plane of reference.

**106** *Primary stress* - a primary stress is one produced by the imposed loading and 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 which considerably exceed the yield strength, will result in failure or at least gross deformations.

Primary membrane stresses are divided into “general” and “local” categories. A general primary membrane stress is one which is so distributed in the structure that no redistribution of load occurs as the result of yielding.

**107** *Primary local membrane stress* - cases arise in which a membrane stress produced by pressure or other mechanical loading and associated with a primary and/or a discontinuity effect produces excessive distortion in the transfer of load to other portions of the structure. Such a stress shall be classified as a primary local membrane stress even though it has some characteristics of a secondary stress. A stressed region may be considered as local if:

$$s_1 \leq 0.5 \sqrt{Rt}$$

and

$$s_2 \geq 2.5 \sqrt{Rt}$$

$s_1$  = distance in the meridional direction over which the equivalent stress exceeds 1.1 f

$s_2$  = distance in the meridional direction to another region where the limits of general primary membrane stress are exceeded

R = mean radius of the vessel

t = wall thickness at the location where the general primary membrane stress limit is exceeded

f = allowable primary membrane stress, as given in 201.

**108** *Secondary stress* - a normal stress or shear stress developed by the constraint 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 which cause the stress to occur.

**109** *Peak stress* - the basic characteristic of a peak stress is that it does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack or a brittle fracture.

**110** *Thermal stress* - a self-balancing stress produced by a non-uniform distribution of temperature or by differing thermal coefficient of expansion.

Thermal stresses may be divided into two types:

1) General thermal stress which is associated with distortion of the structure in which it occurs. General thermal stresses are classified as secondary stresses.

2) Local thermal stress which is associated with almost complete suppression of the differential expansion and thus produces no significant distortion. Such stresses may be classified as local stresses and need only to be considered from a fatigue standpoint.

#### Guidance note:

Examples of local thermal stresses are:

Stress from radial temperature gradient in a cylindrical or spherical shell, stress in a cladding material which has a coefficient of expansion different from that of the base material, stress in a small cold point in a vessel wall.

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## G 200 Design stresses

**201** For design against excessive plastic deformation and bursting, the design equivalent stresses shall not exceed the values given in 300:

$$f = \text{the lesser of } \frac{\sigma_B}{A} \text{ or } \frac{\sigma_F}{B}$$

$$F = \text{the lesser of } \frac{\sigma_B}{C} \text{ or } \frac{\sigma_F}{D}$$

A, B, C and D have the following values:

Material	A	B	C	D
C-Mn steels and Ni-steels	3	2	3	1.5
Austenitic steels	3.5	1.6	3	1.5
Aluminium alloys	4	1.5	3	1.5

For  $\sigma_B$  and  $\sigma_F$ , see A300.

In certain cases the mechanical properties of the welded joint must be taken into consideration when determining the design stress, see A400.

**202** For certain materials, subject to special consideration by the Society, advantage may be taken of enhanced yield stress and tensile strength at temperatures below -105°C.

**203** Stresses may be reduced below the value given in 201 by fatigue analysis, crack propagation analysis and buckling criteria.

**204** Allowable stresses for materials other than those referred to in Sec.2 will be subject to approval in each separate case.

## G 300 Summation of static and dynamic stresses, equivalent stress and stress limits

**301** The calculated stresses for different loading conditions are grouped into five stress categories,  $\sigma_m$ ,  $\sigma_L$ ,  $\sigma_b$ ,  $\sigma_g$  and  $\sigma_f$ .

These symbols do not represent single quantities, but for a 3-dimensional stress condition a set of three normal and three shear stress components in an orthogonal system of coordinates. The unidirectional components are combined to form the three principal stresses,  $\sigma_1$ ,  $\sigma_2$  and  $\sigma_3$ . The equivalent stress at a point is equal to:

$$\frac{1}{\sqrt{2}} \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2}$$

In a two-dimensional stress condition the above formula with  $\sigma_3 = 0$  or the formula in F201 may be used.

**302** General primary membrane stress category - the stresses in this category are designated by the symbol  $\sigma_m$  and are those defined in 106.

The equivalent stress shall not exceed:

$$\sigma_m \leq f$$

**303** Local primary membrane stress category - the stresses in this category are designated by the symbol  $\sigma_L$  and are those defined in 107.

The equivalent stress shall not exceed:

$$\sigma_L \leq 1.5 f$$

**304** General or local primary membrane plus primary bending stress category.

The stresses in the primary bending stress category are designated by the symbol  $\sigma_b$ .

The equivalent stress shall not exceed:

$$\begin{aligned} \sigma_b &\leq 1.5 F \\ \sigma_L + \sigma_b &\leq 1.5 F \\ \sigma_m + \sigma_b &\leq 1.5 F \end{aligned}$$

**305** Primary plus secondary stress category - the stresses in the secondary stress category are designated by the symbol  $\sigma_g$  and are those defined in 108.

The equivalent stress shall not exceed:

$$\begin{aligned} \sigma_m + \sigma_b + \sigma_g &\leq 2.8 F \\ \sigma_L + \sigma_b + \sigma_g &\leq 2.8 F \end{aligned}$$

**306** Peak stress category ( $\sigma_f$ ) - the stresses falling within this category are a combination of all primary, secondary and peak stresses produced by pressure and other loads, and by general and local thermal effects and including the effect of structural discontinuities. The allowable value of equivalent stress shall not exceed the fatigue limit of the material for the specified number of loadings, see A1400.

## H. Independent Tanks Type B, Constructed Mainly of Plane Surfaces

### H 100 General

**101** These requirements apply to independent tanks type B, primarily constructed of plane surfaces, where internal loads are carried mainly in bending of plates and stiffeners.

**102** In addition to requirements given under F100 to F200, the following rules shall be applied.

**103** The scantlings of the tank's strength members shall be based on a complete structural analysis of the tank and are generally not to be less than those for independent tanks type A.

**104** The structural analysis of the various strength members forming the cargo tank shall be carried out using appropriate models. For deep girders, bulkhead panels, bracket zones, etc., where results obtained by applying the beam theory are unreliable, finite element analysis or equivalent methods shall be applied.

**105** Due attention shall be given to:

- boundary conditions
- elastic supports formed by the adjoining strength members.

**106** If frame work analysis is used, the calculation methods applied shall take into account the effect of bending, shear, axial and torsional deformations. Due attention shall be given to:

- shear area variation
- moment of inertia variation
- effective flange.

### H 200 Definition of strength member types

**201** Primary members are supporting members such as webs, stringers and girders consisting of web plate, face plate and effective plating.

Secondary members are stiffeners and beams, consisting of web plate, face plate (if any) and effective plating.

Tertiary members are plate panels between stiffeners.

### H 300 Equivalent stress and summation of static and dynamic stresses

**301** For summation of stresses from different loading conditions and calculation of the equivalent stress, see F200.

**302** Equivalent stresses shall be calculated at the points given below:

- primary and secondary members:  
at the point of maximum equivalent stress
- tertiary members:  
at the centre of the plate panel.

The stresses shall not exceed the limits given in 401.

#### H 400 Design criteria

**401 Design stresses.** Nominal stresses shall not exceed the values given in Table H1 to Table H3.

Notations:

$\sigma_e$  = equivalent stress as given in 300.

$\sigma_F$ ,  $\sigma_{0,2}$  and  $\sigma_B$  are defined in A300.

Table H1 C-Mn steels and Ni-steels		
Type of strength member	Design load condition Item A708 and A600	
	$\sigma_e/\sigma_F$	$\sigma_e/\sigma_B$
Primary	0.70	0.50
Secondary	0.75	0.525
Tertiary	0.80	0.56

Table H2 Austenitic steels		
Type of strength member	Design load condition Item A708 and A600	
	$\sigma_e/\sigma_{0,2}$	$\sigma_e/\sigma_B$
Primary	0.80	0.375
Secondary	0.85	0.40
Tertiary	0.90	0.425

Table H3 Aluminium alloys		
Type of strength member	Design load condition Item A708 and A600	
	$\sigma_e/\sigma_{0,2}$	$\sigma_e/\sigma_B$
Primary	0.75	0.35
Secondary	0.80	0.375
Tertiary	0.85	0.40

Nominal stresses for the load condition A600 shall not exceed 70% of the values given in Table H1 to Table H3.

Allowable stresses in sub-regions and design details will be considered by the Society in each case.

Thermal stresses shall be specially considered.

**402 Stability analysis.** Structures subjected to compressive stresses and or high shear stresses shall be checked against stability. See also F106 and F107. The following buckling modes shall be taken into consideration:

- local buckling of plate between stiffeners
- local buckling of web plate or flange of girders and stiffeners
- torsional buckling of girders and stiffeners
- overall lateral buckling of stiffened plates.

The stability factor is given by:

$$\eta = \sqrt{\left(\frac{\sigma_x}{\sigma_{xcr}}\right)^2 + \left(\frac{\sigma_y}{\sigma_{ycr}}\right)^2 + \left(\frac{\tau_{xy}}{\tau_{xycr}}\right)^2}$$

$\sigma_x$  = actual normal stress in x-direction  
 $\sigma_y$  = actual normal stress in y-direction  
 $\tau_{xy}$  = actual shear stress in the x-y plane.

$\sigma_{xcr}$ ,  $\sigma_{ycr}$  and  $\tau_{xycr}$  are the critical values of the stress components  $\sigma_x$ ,  $\sigma_y$  and  $\tau_{xy}$ .

The critical stresses shall be calculated separately for each component according to the following:

$$\sigma_{xcr} = \sigma_{xel} \text{ if } \sigma_{xel} \leq 0.5 \sigma_F$$

$$= \sigma_F \left(1 - \frac{\sigma_F}{4\sigma_{xel}}\right) \text{ if } \sigma_{xel} > 0.5 \sigma_F$$

$$\sigma_{ycr} = \sigma_{yel} \text{ if } \sigma_{yel} \leq 0.5 \sigma_F$$

$$= \sigma_F \left(1 - \frac{\sigma_F}{4\sigma_{yel}}\right) \text{ if } \sigma_{yel} > 0.5 \sigma_F$$

$$\tau_{xycr} = \tau_{el} \text{ if } \tau_{el} \leq 0.5 \sigma_F / \sqrt{3}$$

$$= \frac{\sigma_F}{\sqrt{3}} \left(1 - \frac{\sigma_F}{4\sqrt{3}\tau_{el}}\right) \text{ if } \tau_{el} > 0.5 \sigma_F / \sqrt{3}$$

$\sigma_{xel}$ ,  $\sigma_{yel}$  and  $\tau_{el}$  are the ideal Euler buckling stresses according to the classical theory of buckling.

$\sigma_F$  (or  $\sigma_{0,2}$ ) is defined in A300.

Table H4 Allowable stability factor $\eta$		
	Design load condition: A600	Design load condition: A708 and A600
Local buckling failure	0.6	1.0
Overall or torsional buckling failure	0.4	0.7

## I. Independent Tanks Type C

### I 100 Loads

**101** In the design of the tank, the loads given in A600, A704, A705, A706, A800, A900, A1000, A1100 and Sec.1 D700 shall be considered.

**102** The internal pressure p used to determine the thickness of any specific part of the tank is given by:

$$p_{eq} = p_0 + (p_{gd})_{max}$$

$p_{eq}$  is determined as detailed in A705 and A706.

**103** For tanks supported in such a way that the deflection of the hull transfers significant stresses to the tank, the wave-induced loads may be required to be calculated as given in A708.

For saddle-supported tanks, the supports are also to be calculated for the most severe resulting acceleration. The most probable resulting acceleration in a given direction  $\beta$  may be found as shown in Fig.1. The half axes in the "acceleration ellipse" may be found from the formulae given in A704.

### I 200 General requirements for design

**201** For design against excessive plastic deformation, cylindrical and spherical shells, dished ends and openings and their reinforcement shall be calculated according to 400, 500 and 600 when subjected to internal pressure only, and according to 704, 804 and 900 when subjected to external pressure only.

**202** An analysis of the stresses imposed on the shell from supports are always to be carried out, see 1000. Analysis of stresses from other local loads, thermal stresses and stresses in parts not covered by 400 and 500 may be required to be submitted. For the purpose of these calculations the stress limits given in G300 apply.

**203** For design against elastic instability, the requirements in 703, 803 and 900 apply.

**204** In special cases, a fatigue analysis according to A1400 may be required.

**205** Only plus-tolerances are allowed on the design wall thickness.

**206** The thickness, including corrosion allowance, after forming of any shell and head, shall not be less than 5 mm for

C-Mn steels and Ni-steels, 3 mm for austenitic steel or 7 mm for aluminium alloy.

**I 300 Design equivalent primary membrane stress**

**301** For design against excessive plastic deformation and bursting, the equivalent primary membrane stress,  $\sigma_t$  shall not exceed the lowest of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_F}{B}$$

A and B have the following values:

Material	A	B
C-Mn steels and Ni-steels	3	2
Austenitic steels	3.5	1.6
Aluminium alloy	4	1.5

$\sigma_F$  and  $\sigma_B$  are defined in A300.

In certain cases the mechanical properties of the welded joint must be taken into consideration when determining the design stress. See A400.

**302** For certain materials, subject to special consideration by the Society, advantage may be taken of enhanced yield strength and tensile strength at temperatures below -105°C.

**303** Allowable stresses for materials other than those referred to in Sec.2, will be subject to approval in each separate case.

**I 400 Cylindrical and spherical shells under internal pressure only**

**401 Symbols**

- t = minimum required thickness of shell, exclusive of corrosion allowance (mm)
- $p_0$  = maximum allowable vapour pressure defined in A300 (bar)
- R = inside radius of shell or shell section (mm)
- e = efficiency (expressed as a fraction) of welded joints
- M = longitudinal bending moment (Nm), e.g. due to:
  - mass loads in a horizontal vessel
  - eccentricity of the centre of working pressure relative to the neutral axis of the vessel
  - friction forces between the vessel and a saddle support.

W = axial force on shell, positive if tensile, excluding pressure load due to  $p_0$  (N)

E = modulus of elasticity (N/mm<sup>2</sup>).

**402** The minimum thickness of a cylindrical, conical and spherical shell for pressure loading only shall be determined from the formulae in Pt.4 Ch.7 Sec.4. The design pressure is given in 102.

The nominal design stress,  $\sigma_t$ , is given in 300.

The joint efficiency for welded joints is: e = 1.0.

**403** The longitudinal stress in a cylindrical shell shall be calculated from the following formula:

$$\sigma_Z = \frac{p_0 R^2}{10(2R + t)t} + \frac{W}{\pi(2R + t)t} + \frac{4M \cdot 10^3}{\pi(2R + t)^2 t}$$

For design against excessive plastic deformation,  $\sigma_Z$  shall not exceed 0.8  $\sigma_t$  e.

Value for  $\sigma_t$ , based on values for  $\sigma_B$  and  $\sigma_{0.2}$  in coldworked or tempered condition will be considered. For design against buckling, the longitudinal compressive stress,  $\sigma_Z$  shall not exceed:

$$\sigma_Z = \frac{0.20E \frac{t}{R}}{1 + 0.004 \frac{E}{\sigma_F}}$$

If applicable,  $\sigma_Z$  is also to be checked for  $p_0 = 0$ .

**I 500 Dished ends concave to pressure**

**501** The minimum thickness of dished ends subjected to pressure on the concave side shall be calculated from the formula in Pt.4 Ch.7 Sec.4.

The design pressure is given in 102.

The nominal design stress,  $\sigma_t$ , shall be equal to the design primary membrane stress given in 300.

The joint efficiency for welded joints is: e = 1.0.

**I 600 Openings and their reinforcement**

**601** Openings and their reinforcement shall be in compliance with Pt.4 Ch.7 Sec.4.

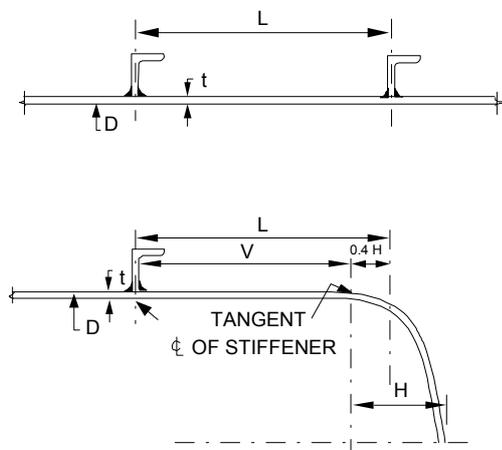
**I 700 Cylindrical shells under uniform external pressure**

**701 Symbols**

- D = outside diameter (mm)
- $D_S$  = diameter to the neutral axis of stiffener (mm)
- t = thickness of plate, exclusive of corrosion allowance (mm)
- E = modulus of elasticity at room temperature (N/mm<sup>2</sup>)
- $\sigma_F$  = defined in A300
- $p_{ed}$  = external design pressure, see A603 (bar)
- n = integral number of waves ( $\geq 2$ ) for elastic instability
- L = effective length between stiffeners, see Fig.5 (mm)
- $L_S$  = length of shell contributing to the moment of inertia of a stiffener (mm)
- v = Poisson's ratio
- Z = coefficient =  $\frac{0.5\pi D}{L}$

$I_X$  = moment of inertia of stiffening ring (mm<sup>4</sup>).

**702** The cylindrical shell shall be checked so that elastic instability or membrane yield does not occur. The allowable design pressure shall be the smaller of the values obtained in 703 and 704.



**Fig. 5**  
Effective length of cylinders subject to external pressure

**703 Calculation of elastic instability**

The pressure  $p_c$ , corresponding to elastic instability of an ideal

cylinder, shall be determined from the following formula:

$$p_c = \frac{20E}{(n^2 - 1) \left[ 1 + \left( \frac{n}{Z} \right)^2 \right]^2} \frac{t}{D} + \frac{20E}{3(1 - \nu^2)} \left( n^2 - 1 + \frac{2n^2 - 1 - \nu}{\left( \frac{n}{Z} \right)^2 - 1} \right) \left( \frac{t}{D} \right)^3$$

where  $n$  is chosen to minimise  $p_c$ . The formula is only applicable when  $n > Z$ . Alternatively,  $p_c$  may be obtained from Fig.6.

The design pressure shall not exceed:

$$p_{ed} = \frac{p_c}{4}$$

#### 704 Calculation of membrane yield

The pressure  $p_y$ , corresponding to a general membrane yield, shall be determined from the following formula:

$$p_y = 20 \frac{\sigma_F t}{D}$$

The design pressure shall not exceed:

$$p_{ed} = \frac{p_y}{3}$$

#### 705 Stiffening rings

Stiffening rings composed of structural shapes welded continuously to the inside or outside of the shell, shall have a moment of inertia,  $I_X$ , for the combined shell and structural shape of not less than:

$$I_X = \frac{0.18 D p_{ed} L D_S^2}{10E}$$

The permissible length,  $L_S$ , of the shell contributing to the moment of inertia of the stiffening section, shall be:

$$L_S = 0.75 \sqrt{Dt}$$

Stiffening rings shall extend completely around the circumference of the shell.

### I 800 Spherical shells under uniform external pressure

#### 801 Symbols

- R = outside radius of sphere (mm)
- t = thickness of plate, exclusive of corrosion allowance (mm)
- E = modulus of elasticity in N/mm<sup>2</sup> at room temperature
- $\sigma_F$  = defined in A300
- $p_{ed}$  = external design pressure, see A603 (bar).

**802** The spherical shell shall be checked so that elastic instability or membrane yield stress does not occur. The allowable design pressure shall be the smaller of the values obtained in 803 and 804.

**803** Calculation of elastic instability. The pressure  $p_c$ , corresponding to elastic instability of a spherical shell, shall be determined from the following formula:

$$P_c = 2.4E \left( \frac{t}{R} \right)^2$$

The design pressure shall not exceed:

$$p_{ed} = \frac{p_c}{3}$$

**804** Calculation of membrane yield. The pressure  $p_y$ , corresponding to general membrane yield, shall be determined from the following formula:

$$p_y = 20 \frac{\sigma_F t}{R}$$

The design pressure shall not exceed:

$$p_{ed} = \frac{p_y}{3}$$

### I 900 Dished ends convex to pressure

**901** Hemispherical ends shall be designed as spherical shells as given in 800.

**902** Torispherical ends shall be designed as spherical shells as given in 800, taking the crown radius as the spherical radius, and in addition, the thickness shall not be less than 1.2 times the thickness required for an end of the same shape subject to internal pressure.

**903** Ellipsoidal ends shall be designed as spherical shells as given in 800, taking the maximum radius of the crown as the equivalent spherical radius, and in addition, the thickness shall not be less than 1.2 times the thickness required for an end of the same shape subject to internal pressure.

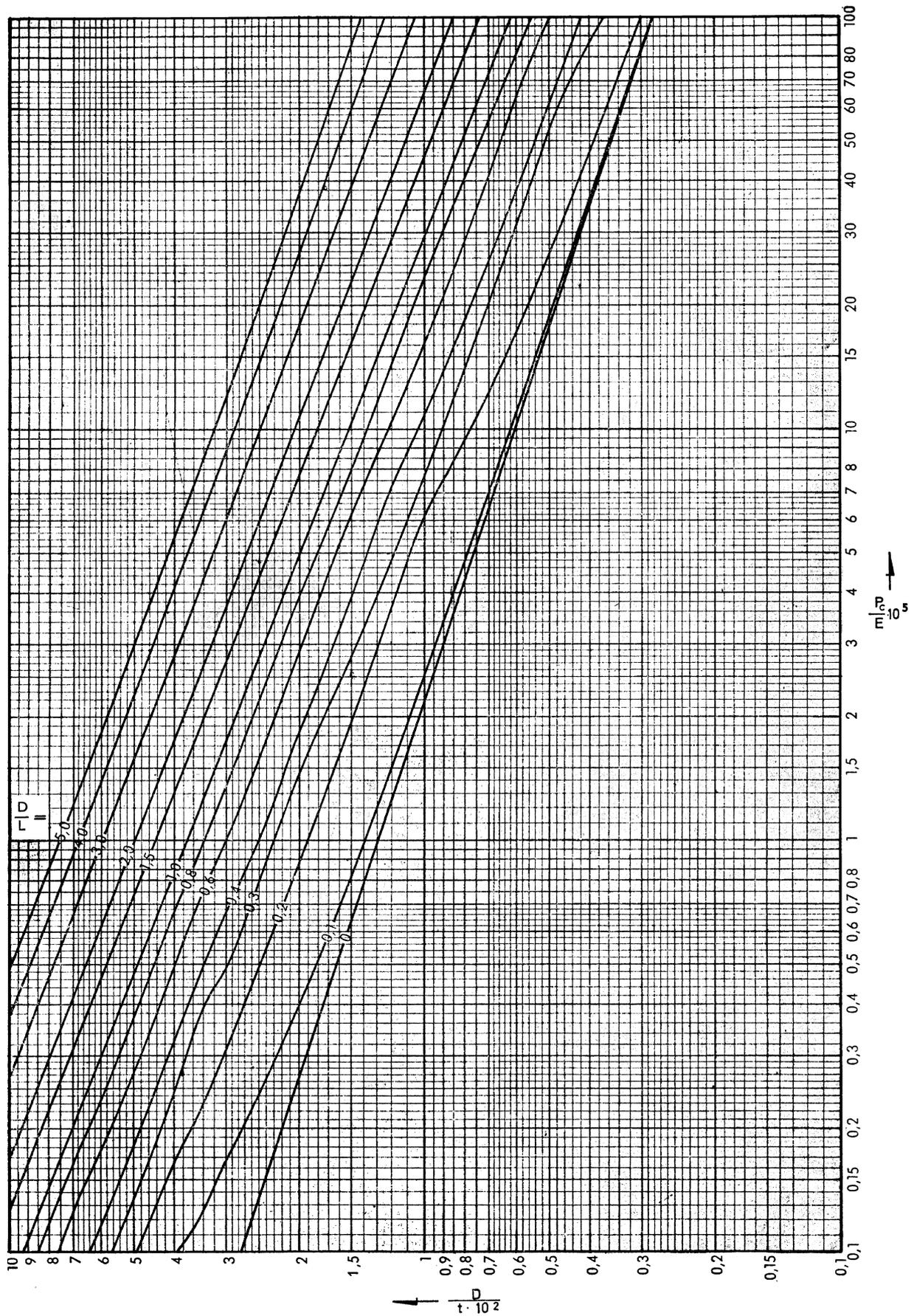


Fig. 6  
 Calculation of  $p_c$

## I 1000 Supports

**1001** The supporting members shall be arranged in such a way as to provide for the maximum imposed loads given in 100.

In designs where significant compressive stresses are present, the possibility of buckling shall be investigated. The tank shall be able to expand and contract due to temperature changes without undue restrains.

**1002** Where more than two supports are used, the deflection of the hull girder shall be considered.

### Guidance note:

Horizontal tanks supported by saddles should preferably be supported by two saddle supports only.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

**1003** Saddles shall afford bearing over at least 140° of the circumference.

**1004** Calculation of stresses in a cylindrical tank shall include:

- longitudinal stresses at midspan and at supports
- tangential shear stress at supports and in dished ends, if applicable
- circumferential stresses at supports.

**1005** For tanks supported in such a way that deflections of the hull transfer significant stresses to the tank, a three-dimensional analysis for the evaluation of the overall structural response of the tank may have to be carried out as required for tanks type B. In that case the same stress limits as given in G300 for tanks type B apply.

**1006** The circumferential stresses at supports shall be calculated by a procedure acceptable to the Society for a sufficient number of load cases as defined in 103.

The acceptance of calculations based on methods given in recognised standards will be considered from case to case.

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

$$\sigma_e = \sqrt{(\sigma_n + \sigma_b)^2 + 3\tau^2} \leq 0.57\sigma_B \text{ or } 0.85\sigma_F$$

- $\sigma_e$  = equivalent stress (N/mm<sup>2</sup>)
- $\sigma_n$  = normal stress in the circumferential direction of the stiffening ring (N/mm<sup>2</sup>)
- $\sigma_b$  = bending stress in the circumferential direction of the stiffening ring (N/mm<sup>2</sup>)
- $\tau$  = shear stress in the stiffening ring (N/mm<sup>2</sup>).

The buckling strength of the stiffening ring shall be examined.

### Guidance note:

The following assumptions may be made when calculating stresses in stiffening rings of horizontal cylindrical tanks:

- 1) The stiffening ring may 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 may be taken as:

- For cylindrical shells:

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

r = mean radius of the cylindrical shell (mm)  
t = shell thickness (mm).

- For longitudinal bulkheads (in the case of lobe tanks):

the effective width should be determined according to established standards. A value of  $20 t_b$  on each side of the web may be taken as a guidance value.

$t_b$  = bulkhead thickness (mm).

- 2) 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.
- 3) For calculation of the 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 should not show any tensile forces.

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## I 1100 Manufacture and workmanship

**1101** The tanks shall be manufactured by works approved by the Society for manufacturing of class I pressure vessels.

**1102** The workmanship shall comply with the requirements in Pt.4 Ch.7 Sec.8, for class I pressure vessels. Special precautions shall be taken to avoid notches as undercutting, excessive reinforcement, cracks and arc flashes. All welds, nozzle welds included, shall be full penetration welds, unless specially approved for small nozzle diameters.

**1103** Tanks made of carbon and carbon-manganese steel shall be thermally stress-relieved after welding if the design temperature is below -10°C.

The soaking temperature and holding time shall be as given in Pt.4 Ch.7 Sec.8 Table C2. For nickel alloy steels and austenitic stainless steel, the requirements for heat treatment will be considered in each case.

In the case of large cargo pressure vessels of carbon or carbon-manganese steel for which it is difficult to perform the heat treatment, mechanical stress relieving by pressurizing may be carried out as an alternative to the heat treatment subject to the following conditions:

- 1) Complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates shall be heat treated before they are welded to larger parts of the pressure vessel.
- 2) The mechanical stress relieving process shall preferably be carried out during the hydrostatic pressure test required by N304, by applying a higher pressure than the test pressure required by N304. The pressurizing medium shall be water.
- 3) For the water temperature, N304 applies.
- 4) Stress relieving shall be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure.
- 5) The maximum stress relieving pressure shall be held for two hours per 25 mm of thickness but in no case less than two hours.
- 6) The upper limits placed on the calculated stress levels during stress relieving shall be the following:

- equivalent general primary membrane stress:  $0.9 R_e$
- equivalent stress composed of primary bending stress

plus membrane stress:  $1.35 R_e$

where  $R_e$  is the specific lower minimum yield stress or 0.2% proof stress at test temperature of the steel used for the tank.

- 7) Strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges shall be included in the mechanical stress relieving procedure.
- 8) The test procedure should demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again up to the design pressure.
- 9) High stress areas in way of geometrical discontinuities such as nozzles and other openings shall be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect shall be given to plates exceeding 30 mm in thickness.
- 10) Steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 shall generally not be mechanically stress relieved. If, however, the yield stress is raised by a method giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case.
- 11) Mechanical stress relieving cannot be substituted for heat treatment of cold formed parts of tanks if the degree of cold forming exceeds the limit above which heat treatment is required.
- 12) The thickness of the shell and heads of the tank shall not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved.
- 13) Local buckling shall be guarded against particularly when tori-spherical heads are used for tanks and domes.
- 14) The procedure for mechanical stress relieving shall be submitted beforehand to the Society for approval.

**1104** Out of roundness shall not exceed the limit given in Pt.4 Ch.7 Sec.8 B304.

Irregularities in profile shall not exceed the limit given in Pt.4 Ch.7 Sec.8 B305, or 0.2% of D, whichever is the greater, with a maximum equal to the plate thickness. D is the diameter of the shell. Measurements shall be made from a segmental circular template having the design inside or outside radius, and having a chord length corresponding to the arc length obtained from Fig.7. For spheres, L is one half the outside diameter. For shells under internal pressure, the chord length need not exceed 0.17 D.

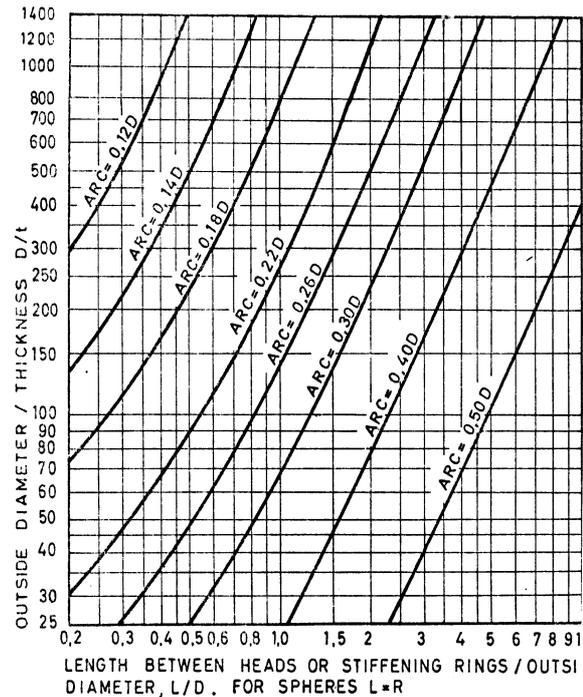
## J. Internal Insulation Tanks

### J 100 General

**101** The effects of all static and dynamic loads shall be considered to determine the suitability of the tank with respect to:

- fatigue failure
- crack propagation from both free and supported surfaces
- adhesive and cohesive strength
- compressive, tensile and shear strength.

Statistical wave load analysis, finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach shall be carried out.



**Fig. 7**  
Arc length for determining deviation for true form

**102** A complete analysis of the response of ship, cargo and any ballast to accelerations and motions in irregular waves of the particular ship shall be performed according to A700 unless such analysis is available for a similar ship.

**103** The effects of fatigue loading shall be determined in accordance with A1400 or by an equivalent method.

### J 200 Interaction internal insulation and supporting structure

**201** Special attention shall be given to crack resistance and to deflections of the inner hull or independent tank structure and their compatibility with the insulation materials. A three-dimensional structural analysis shall be carried out to the satisfaction of the Society. This Analysis shall evaluate the stress levels and deformations contributed either by the inner hull or by the independent tank structure or both and shall also take into account the internal pressure as indicated in A706. Where water ballast spaces are adjacent to the inner hull forming the supporting structure of the internal insulation tank, the analysis shall take account of the dynamic loads caused by water ballast under the influence of ship motions.

**202** The allowable stresses and associated deflections for the internal insulation tank and the inner hull structure or independent tank structure shall be determined in each particular case.

**203** Thicknesses of plating of the inner hull or of an independent tank shall take into account the internal pressure as indicated in A706. Tanks constructed of plane surfaces shall comply with the rules for deep tanks.

### J 300 Prototype testing

**301** In order to confirm the design principles, prototype testing of composite models including structural elements shall be carried out under combined effects of static, dynamic and thermal loads.

**302** Test conditions shall represent the most extreme service conditions the cargo containment system will be exposed to during the lifetime of the ship, including thermal cycles. For

this purpose, 400 thermal cycles are considered to be a minimum, based upon 19 round voyages per year; where more than 19 round voyages per year are expected, a higher number of thermal cycles will be required. These 400 thermal cycles may be divided into 20 full cycles (cargo temperature to 45°C) and 380 partial cycles (cargo temperature to that temperature expected to be reached in the ballast voyage).

**303** Models shall be representative of the actual construction including corners, joints, pump mounts, piping penetrations and other critical areas, and shall take into account variations in tank material properties, workmanship and quality control.

**304** Combined tension and fatigue tests shall be carried out to evaluate crack behaviour of the insulation material in the case where a through crack develops in the inner hull or independent tank structure. In these tests, where applicable, the crack area shall be subjected to the maximum hydrostatic pressure of the ballast water.

#### **J 400 Quality control procedures during fabrication**

**401** For internal insulation tanks, in order to ensure uniform quality of the material, quality control procedures including environmental control, application procedure qualification, corners, penetrations and other design details, materials specification, installation and production testing of components shall be to standards developed during the prototype test programme.

**402** A quality control specification including maximum size of constructional defects, tests and inspections during the fabrication, installation and also sampling tests at each of these stages shall be to the satisfaction of the Society.

**403** The inspection and non-destructive testing of the inner hull or the independent tank structures supporting internal insulation tanks shall take into account the design criteria as given in 200. The schedule for inspection and non-destructive testing shall be to the satisfaction of the Society.

#### **J 500 Repair procedure**

**501** For internal insulation tanks, repair procedures shall be developed during the prototype testing programme for both the insulation material and the inner hull or the independent tank structure.

### **K. Welding Procedure Tests**

#### **K 100 Cargo tanks and cargo process pressure vessels**

**101** The requirements for welding procedure tests for cargo tanks and cargo process pressure vessels are given in Pt.2 Ch.3 Sec.5.

#### **K 200 Secondary barriers**

**201** Welding procedure tests are required for secondary barriers and shall be similar to those required for cargo tanks.

### **L. Weld Production Tests**

#### **L 100 General**

**101** Weld production tests shall be carried out to the extent given in 200 for the different types of tanks. The test requirements are given in 400.

**102** For all cargo process pressure vessels and cargo tanks except integral and membrane tanks, production tests are generally to be performed for approximately each 50 m of butt

weld joints and shall be representative of each welding position and plate thickness.

**103** For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Society.

**104** Tests other than those specified in 200, may be required for cargo tanks or secondary barriers at the discretion of the Society.

#### **L 200 Extent of testing**

**201** For independent tanks types A and B and semi-membrane tanks, the production tests shall include the following tests:

— Two bend tests, macro etching and when required for procedure tests, one set of three Charpy V-notch tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimen having the notch alternately located in the centre of the weld and in the heat-affected zone (most critical location based on procedure qualification results). If only one production test is required, Charpy V-notch tests shall be made for both centre of weld and heat-affected zone. For austenitic stainless steel, all notches shall be in the centre of the weld.

**202** For independent tanks type C and cargo process pressure vessels, transverse weld tensile tests are required in addition to those tests listed in 201.

**203** Production tests for integral and membrane tanks will be dealt with in each separate case.

#### **L 300 Preparation of production weld test**

**301** One production weld test consists of two plates which shall be cut from the plate or the plates from which the tank or pressure vessel shall be made.

The plates shall be well fastened to the tank material and have sufficient dimensions to give cooling conditions as far as possible the same as for the production welding. Each plate is at least to be 150 x 300 mm.

The test pieces shall not be detached from the shell plate until they have been properly marked and stamped by the surveyor.

**302** The two halves of the test assembly shall be tack welded to the tank or pressure vessel in such a manner that the weld of the test assembly forms a direct continuation of the joints in the product. The main rolling direction for the plates in the production weld test shall be parallel to the main rolling direction for the tank material at the place where the production weld test is situated. The weld in the test assembly shall be laid at the same time as the weld in the product, by the same welder, and the same welding parameters shall be used.

**303** If the production weld test cannot be made as a direct continuation of the weld in the tank or pressure vessel (e.g. a circumferential joint) it is, as far as possible, to be similar to the weld in the product.

**304** The production weld test shall be heat-treated as the product.

**305** The weld reinforcement shall be machined flush with the plate surface on both sides of the test assembly.

#### **L 400 Test requirements**

**401** The dimensions of test pieces shall be as required for the welding procedure test detailed in Pt.2 Ch.3 Sec.5.

**402** Test requirements are given in Pt.2 Ch.3 Sec.5.

## M. Requirements for Weld Types and Non-Destructive Testing (NDT)

### M 100 General

**101** Non-destructive testing, NDT, shall be performed in accordance with approved procedures. All test procedures shall be in accordance with recognised standards.

**102** Basic requirements are given in Pt.2 Ch.3 Sec.7.

### M 200 Extent of testing

**201** The requirements to weld type and extent of non-destructive testing are given in Table M1.

**202** The repair of defects revealed during non-destructive testing shall be carried out according to agreement with the

surveyor. All such weld repairs shall be inspected using the relevant testing method. If defects are detected, the extent of testing shall be increased to the surveyor's satisfaction.

**203** When random radiographic testing is performed and the radiograph reveals unacceptable defects, two further exposures shall be made, preferably one on each side of the initial one.

When two or more radiographs (including possible additional ones) of the same weld reveal an unacceptable defect level, the entire length of the weld in question shall be radiographed.

### M 300 Acceptance criteria

**301** The quality of the welds in aluminium shall comply with ISO 10042 quality level B, and the quality of the welds in steel shall comply with ISO 5817 quality level B.

**Table M1 Requirements for tank welds and non-destructive testing**

Tank type	Weld type requirement	Non-destructive testing	
		Radiography	Ultrasonic testing surface crack detection
Integral	Full penetration	Special weld inspection procedures and acceptable standards shall be submitted by the designers for approval	
Membrane	Subject to special consideration		
Semi-membrane	As for independent tanks or for membrane tanks as appropriate	<i>Radiography:</i>	<i>Ultrasonic testing:</i> — reinforcement rings around holes 100%.  <i>Surface crack detection:</i> — all butt welds in shell 10% — reinforcement rings around holes, nozzles etc. 100%.  The remaining tank structure including the welding of girders, stiffening rings and other fittings and attachments, shall be examined by ultrasonic and surface crack detection as considered necessary.
Independent, type A	For dome to shell connections, tee welds of the full penetration type are acceptable. All welded joints of the shell shall be of the butt weld full penetration type. The same applies to the joints of face plates and web plates of girders and stiffening rings.  Except for small penetrations on domes, nozzle welds are also generally to be designed with full penetration.	a) Cargo tank design temperature lower than - 20°C. All full penetration welds of the shell plating 100%.  b) Cargo tank design temperature higher than - 20°C. All full penetration welds in way of intersections and at least 10% of the remaining full penetration welds of tank shell.  c) Butt welds of face plates and web plates of girders, stiffening rings etc. shall be radiographed as considered necessary.	
		<i>Radiography:</i> a) All butt welds in shell plates 100%. b) Butt welds of face plates and web plates of girders, stiffening rings etc. shall be radiographed as considered necessary.	
Independent, type B	For tank type C, see also I1102		
Independent, type C			
Internal insulation tanks and supporting structure		Quality control procedures according to J400	
Secondary barriers		<i>Radiography:</i> When the outer shell of the hull is part of the secondary barrier, intersection of all vertical butt welds and seams in the side shell shall be tested. Where the sheerstrake forms a part of the secondary barrier, all vertical butt welds in the sheerstrake shall be tested.  See Pt.2 Ch.3 Sec.7.	<i>Surface crack detection:</i> — See Pt.2 Ch.3 Sec.7.

## N. Testing of Tanks

### N 100 Integral tanks

**101** All cargo tanks shall be subjected to a hydrostatic structural test in accordance with Pt.2 Ch.3 Sec.8. In addition, each tank shall be subjected to a leak test. The leak test may be performed in combination with the structural test or separately. Tank boundary welds shall not be painted before the leak test is carried out.

**102** If the design vapour pressure  $p_0$  is higher than the normal value 0.25 bar, but less than 0.7 bar as allowed by Sec.1 D100, or if a vapour pressure higher than  $p_0$  shall be used under harbour conditions as allowed by A601, the structural test will be considered in each case. The test which may be a hydrostatic or a hydropneumatic test, is in general to be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tanks correspond at least to the MARVS or the increased vapour pressure allowed in harbour conditions.

### N 200 Membrane and semi-membrane tanks

**201** For ships fitted with membrane or semi-membrane tanks, cofferdams and all spaces which may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically or hydropneumatically tested in accordance with Pt.2 Ch.3 Sec.8. In addition, any other ship hold structure supporting the membrane shall be given a leak test. Pipe tunnels and other compartments which do not normally contain liquid, are not required to be hydrostatically tested.

**202** Each tank shall be subjected to an adequate leak test.

### N 300 Independent tanks

**301** Each independent tank shall be subjected to a hydrostatic or hydropneumatic test.

**302** For tanks type A, this test shall be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tank corresponds at least to the MARVS or the higher vapour pressure allowed in harbour condition (see A601). When hydropneumatic test is performed, the conditions shall simulate, as far as possible, the actual loading of the tank and of its supports.

**303** For tanks type B, the test shall be performed as for tanks type A. Moreover, 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 exceed 75% of the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

**304** Each tank type C, when completely manufactured, shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than  $1.5 p_0$ , but in no case during the pressure test is the calculated primary membrane stress at any point to exceed 90% of the yield stress of the material (as

fabricated) at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels except simple cylindrical and spherical pressure vessels.

Further:

- the temperature of the water used for the test should be at least 30°C above the nil ductility transition temperature of the material as fabricated.
- the pressure should be held for two hours per 25 mm of thickness, but in no case less than two hours.

**305** Where necessary for tanks type C, and with the specific approval of the Society, a hydropneumatic test may be carried out under the conditions prescribed in 304.

**306** All tanks shall be subjected to a leak testing, which may be performed in combination with the structural test mentioned above or separately.

**307** On ships using independent tanks type B, at least one tank and its support shall be instrumented to confirm stress levels, unless the design and arrangement for the size of the ship involved are supported by full scale experience.

Similar instrumentation may be required by the Society for independent tanks type C, dependent on their configuration and on the arrangement of their supports and attachments.

### N 400 Internal insulation tanks

**401** In ships fitted with internal insulation tanks where the inner hull is the supporting structure, all inner hull structure shall be hydrostatically or hydropneumatically tested taking into account the MARVS.

**402** In ships fitted with internal insulation tanks where independent tanks are the supporting structure, the independent tanks shall be tested in accordance with N300.

**403** For internal insulation tanks where the inner hull structure or an independent tank structure acts as a secondary barrier, a leak test of these structures shall be carried out using techniques to the satisfaction of the Society.

**404** These tests in 401 to 403 shall be performed before the application of the materials which will form the internal insulation tank.

**405** Requirements as to leak testing after completion will be determined in each separate case.

**406** The insulation materials of internal insulation tanks shall be subjected to additional inspection in order to verify their surface conditions after the third loaded voyage of the ship, but not later than the first six months of the ship's service after building or a major repair work is undertaken on the internal insulation tanks.

### N 500 Secondary barriers

**501** Requirements with respect to pressure and leak testing of secondary barriers will be decided in each separate case.

## SECTION 6 PIPING SYSTEMS IN CARGO AREA

### A. General

#### A 100 Application

**101** The requirements of this Section are additional to those of Pt.4. Regarding materials, see also Sec.2.

#### A 200 General

**201** The temperature in a steam pipe and any other hot pipeline shall not exceed 220°C in hazardous space or area, or in any non-hazardous area protected by mechanical ventilation.

**202** Pipe connections to engine or boiler rooms shall not pass through hold spaces serving as secondary barriers.

### B. Pumping and Piping Systems for Bilge, Ballast and Fuel Oil

#### B 100 General

**101** There shall be no connection between the piping systems serving the cargo area and the piping systems in the remainder of the ship, except as permitted in 102.

**102** Ballast spaces, including wet duct keels used as ballast piping, fuel oil tanks and non-hazardous spaces may be connected to pumps in the engine room. Dry duct keels with ballast piping passing through, (except for ships with integral tanks, see Sec.3 C404) may be connected to pumps in the engine rooms, provided the connections are led directly to the pumps and the discharge from the pumps led directly overboard with no valves or manifolds in either line, which could connect the line from the duct keel to lines serving gas safe spaces. Pump vents shall not be open to the engine room.

**103** All normally dry spaces (not served by ballast, fuel or cargo system) within the cargo area shall be fitted with bilge or drain arrangements. Spaces not accessible at all times shall have sounding pipes. Spaces without permanent ventilation system or an approved pressure/vacuum relief system, shall have air pipes.

#### B 200 Hold spaces, interbarrier spaces

**201** Where cargo is carried in a cargo containment system not requiring a secondary barrier, hold spaces shall be provided with suitable drainage arrangements not connected with the machinery space. Means of detecting leakage into the hold space shall be provided.

**202** Where there is a secondary barrier, suitable arrangements for dealing with any leakage into the hold or insulation spaces through adjacent ship structure shall be provided. The suction shall not be lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.

**203** The hold or inter-barrier spaces of type A independent tank ships shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements should provide for the return of any cargo leakage to the liquid cargo piping. Such a system shall be provided with a removable spool piece.

**204** In the case of internal insulation tanks, means or arrangements of detecting leakage and drainage are not required for inter-barrier spaces and spaces between the secondary barrier and the inner hull or independent tank structure that are completely filled by insulation material, complying with Sec.7 C203.

### C. Cargo Piping Systems

#### C 100 General

**101** The requirements in 200 to 600 apply to cargo and cargo process piping including vapour piping and vent lines of safety valves or similar piping. Instrument piping not containing cargo, is exempted from these requirements.

#### C 200 Materials and testing of materials

**201** Materials for piping system for liquefied gases shall comply with the requirements of Sec.2 D.

**202** Some relaxation may, however, be permitted in the quality of the material of open ended vent piping, provided the temperature of the cargo at atmospheric pressure is -55°C or higher, and provided no liquid discharge to the vent piping can occur.

Similar relaxation may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside of membrane and semi-membrane tanks.

**203** Materials having a melting point below 925°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.

#### C 300 Arrangement and general design

**301** All pipes shall be mounted in such a way as to minimize the risk of fatigue failure due to temperature variations or to deflections of the hull girder in a seaway. If necessary, they shall be equipped with expansion bends. Use of expansion bellows will be especially considered. Slide type expansion joints will not be accepted outside of cargo tanks. If necessary, expansion joints shall be protected against icing.

**302** Means for effective drainage and gas-freeing of the cargo piping systems shall be provided. Loading and discharge pipes shall be equipped with a connection leading to the escape gas pipe systems of the cargo tank pressure relief valves. This connection shall be equipped with a lockable shut-off valve or similar closing device which shall be closed under normal conditions. The connection is only to be open when pipes and tanks are being gas-freed.

**303** All connections to independent tanks are normally to be mounted above the highest liquid level in the tanks and in the open air above the weather deck.

**304** When the temperature of cargo pipes may fall below -55°C, the connections to the tank shall be designed so as to reduce thermal stresses at cooling-down periods.

**305** For cargo tanks with MARVS not exceeding 0.7 bar, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, shall have shutoff valves located as close to the tank as practicable. These valves may be remotely controlled but should be capable of local manual operation and provide full closure. One or more remotely controlled emergency shutdown valves shall be provided on the ship for shutting down liquid and vapour cargo transfer between ship and shore. Such valves may be arranged to suit the ship's design and may be the same valve as required in 308 and shall comply with the requirements of 309.

**306** For cargo tanks with a MARVS exceeding 0.7 bar, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, shall be equipped with manually operated stop valve and a remotely controlled emergency shutdown valve. 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 309, is capable of local manual operation and provides full closure of the line.

The emergency shutdown valves shall be released as mentioned in 400.

**307** The requirements for emergency shut-down valves given in 306 are not compulsory for the following connections:

- manometer connections with bores 1.5 mm diameter or less
- test cocks with bores 1.5 mm diameter or less.

**308** Each liquid and vapour shore connecting point shall be equipped with a manually operated stop valve and an emergency shut-down valve fitted in series, or a combined manually operated stop valve and emergency shut down valve. Each vapour connection shall be fitted with an emergency shut-down valve. The valve shall be remotely operable and also provided with means for local operation in case of loss of hydraulic or pneumatic power supply, e.g. by mechanical means or by portable hydraulic hand pump. The emergency shut-down valves shall be released as mentioned in 400.

**309** Emergency shut-down valves shall be of the “fail-closed” (closed on loss of power) type and be capable of local manual closing operation. Emergency shutdown valves in liquid piping shall fully close under all service conditions within 30 s of actuation as measured from the time of manual or automatic initiation to full closure. This is called the total shut-down time and is made up of a signal response time and a valve closure time. The valve closure shall be such as to avoid surge pressures in pipelines. Information about the closing time of the valves and their operating characteristics shall be available on board and the closing time shall be verifiable and reproducible. Such valves shall close in such a manner as to cut off the flow smoothly.

**310** In connections with pipe diameters less than 50 mm nominal inside diameter, the emergency shut-down valves required by 306 may be replaced by excess flow valves. 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 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 equalisation of pressure after an operating shut-down.

**311** Pressure relief valves shall be installed in pipes where gas may be trapped, and the pipes are not designed for the saturation pressure corresponding to the temperature of +45°C of any cargo to be transported.

Pipelines or components which may be isolated in a liquid full condition shall be provided with relief valves.

Pressure relief valves as mentioned above, shall be set to open at a pressure of 1.0 to 1.1 times the design pressure of the pipes.

**312** Relief valves discharging liquid cargo from the cargo 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 which may flow into the vent system. Relief valves on cargo pumps shall discharge the pump suction.

**313** Suitable means shall be provided to relieve the pressure and remove liquid contents from cargo loading and discharging crossover headers to the cargo tanks or other suitable location prior to disconnecting the cargo hoses.

**314** Low temperature piping shall be thermally insulated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

**315** 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 for ships intended to carry liquefied gases with boiling points lower than -30°C. The protecting arrangement shall consist of a liquid-tight insulation (a wooden deck or a free, elevated drip tray), or it shall be made from a steel grade corresponding to the requirements for secondary barriers. The insulation or special steel deck shall extend to the ship's side and shall have a width of at least 1.2 m. The deck area shall be bounded by coamings on all sides except on the deck corner side.

The coaming height shall be at least 150 mm.

Elevated drip trays shall measure at least 1.2 x 1.2 m and have a volume of at least 200 litres. Such trays shall be drained over the ship's side by a pipe which preferably leads down into the sea.

**316** All cargo piping shall be electrically bonded to the ship's hull. Bonding straps across stainless steel flanges with bolts and nuts of stainless steel are not required. If carbon-manganese steel is not fitted with bonding straps across the flanges, it shall be checked for electric bonding. The electrical bonding is sufficient, when the electrical resistance between piping and the hull does not exceed 10<sup>6</sup> Ohm.

Cargo piping sections of piping components which are not permanently connected to the hull by permanent piping connections, or where such connections are removable e.g. for removal of spool pieces, shall be electrically bonded to the hull by special bonding straps.

**Guidance note:**

The value of resistance 10<sup>6</sup> Ohm may be achieved without the use of bonding straps where cargo piping systems and equipment are directly, or via their supports, either welded or bolted to the hull of the ship. It will be generally necessary initially to achieve a resistance value below 10<sup>6</sup> Ohm, to allow for deterioration in service.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

**317** Sprayers or similar devices shall be fitted for even cooling of the tanks.

**318** Where cargo transfer is by means of cargo pumps not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank. 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 transfer means.

**319** The procedure for transfer of cargo by gas pressurisation shall preclude lifting of the relief valves during such transfer. Gas pressurisation may be accepted as a means of transfer of cargo for those tanks so designed that the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation.

**320** When pumps situated in different tanks are discharging into a common header, stop of the pumps shall be alarmed at the centralised cargo control position.

**C 400 Control system for emergency shut-down valves**

**401** The emergency shut-down valves mentioned in 305, 306 and 308, shall be arranged for release from at least one position forward of and at least one position abaft the cargo area, and from an appropriate number of positions within the cargo area, dependent on the size of the ship. One of these locations shall be the cargo loading station or cargo control room.

**402** The control system is also to be provided with fusible elements designed to melt at temperatures of approximately 100°C which will cause the emergency shut-down valves to close in the event of fire. Locations for such fusible elements shall include the tank domes and loading stations.

**403** Pumps and compressors shall be arranged to stop if the emergency shut-down valves mentioned in 306 or 308 are released.

### C 500 Piping design

**501** The requirements apply to piping inside and outside the cargo tanks. However, the Society may accept relaxation from these requirements for piping inside cargo tanks and open ended piping.

**502** The piping system shall be joined by welding with a minimum of flange connections. Gaskets shall be protected against blow-out.

**503** Pipe wall thicknesses shall be calculated according to Pt.4 Ch.6 Sec.6. The design pressure  $p$ , in the formula for  $t_0$ , is the maximum pressure to which the system may be subjected in service, as detailed in 504.

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

- 1) For vapour piping systems or components which may be separated from their relief valves and which may contain some liquid, the saturated vapour pressure at 45°C, or higher or lower if agreed upon by the Society (See Sec.5 A601); or
- 2) For systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Society (See Sec.5 A601), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or
- 3) The MARVS of the cargo tanks and cargo processing systems; or
- 4) The pressure setting of the associated pump or compressor discharge relief valve if of sufficient capacity; or
- 5) The maximum total discharge or loading head of the cargo piping system; or
- 6) The relief valve setting on a pipeline system if of sufficient capacity; or
- 7) A pressure of 10 bar except for open ended lines where it shall not be less than 5 bar.

**505** For pipes made of steel including stainless steel, the permissible stress to be considered in the formula of Pt.4 Ch.6 Sec.6 is the lower of the following values:

$$\frac{\sigma_B}{2.7} \text{ or } \frac{\sigma_F}{1.8}$$

$\sigma_B$  = specified minimum tensile strength at room temperature (N/mm<sup>2</sup>)

$\sigma_F$  = specified lower minimum yield stress or 0.2% proof stress at room temperature (N/mm<sup>2</sup>).

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

**506** The minimum thickness shall be in accordance with Pt.4 Ch.6 Sec.6 Table A3 for austenitic stainless steel, and Table A2 "Pipes in general" for C-Mn steel.

**507** Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipe due to superimposed loads from supports, ship deflection or other causes, the wall thickness shall be increased over that required by 503 or, if this is impractical or would cause excessive local stresses, these loads shall be reduced, protected against or eliminated by other design methods.

**508** Flanges, valves, fittings, etc. shall be in accordance with a recognised standard taking into account the design pressure

defined under 504. Flanges not complying with a recognised standard, shall be to the satisfaction of the Society.

For bellows expansion joints used in vapour service, a lower minimum design pressure than defined in 504 may be accepted.

**509** The following types of connections may be considered for direct connection of pipe lengths (without flanges):

- 1) Butt welded joints with complete penetration at the root may be used in all applications. For design temperature below -10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 10 bar and design temperatures  $\leq -10^\circ\text{C}$ , backing rings shall be removed.
- 2) Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Society, are only to be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.
- 3) Screwed couplings acceptable to the Society are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

**510** Flanges shall be of the welding neck, slip-on or socket welding type. For all piping (except open ended lines), the following restrictions apply:

- 1) For design temperatures  $< -55^\circ\text{C}$  only welding neck flanges shall be used.
- 2) For design temperatures  $< -10^\circ\text{C}$  slip-on flanges shall not be used in nominal sizes above 100 mm and socket welding flanges shall not be used in nominal sizes above 50 mm.

**511** Piping connections other than those mentioned above, may be accepted upon consideration in each case.

**512** Postweld heat treatment is required for all butt welds of pipes made with carbon, carbon-manganese and low-alloy steels. The Society 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.

**513** When the design temperature is  $-110^\circ\text{C}$  or lower, a complete stress analysis for each branch of the piping system shall be submitted. This analysis shall take into account all stresses due to weight of pipes with cargo (including acceleration if significant), internal pressure, thermal contraction and loads induced by movements of the ship. For temperatures above  $-110^\circ\text{C}$ , a stress analysis may be required by the Society. In any case, consideration shall be given to thermal stresses, even if calculations need not to be submitted. The analysis shall be carried out according to Pt.4 Ch.6 Sec.6 or to a recognised code of practice.

### C 600 Welding procedure and production tests

**601** Welding procedure tests are required for cargo piping and shall be similar to those required for cargo tanks. Unless especially agreed otherwise, the test requirements shall be in accordance with Pt.2 Ch.3 Sec.5.

### C 700 Testing

**701** The requirements for testing apply to piping inside and outside the cargo tanks. However, relaxation from these requirements may be accepted for piping inside cargo tanks and open ended piping.

**702** In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests are required:

- 1) For butt welded joints for piping systems with design temperatures lower than  $-10^{\circ}\text{C}$  and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, 100% radiographic testing is required.
- 2) When such butt welded joints of piping sections are made by automatic welding processes in the pipe fabrication shop, upon special approval, the extent of radiographic inspection may be progressively reduced but in no case to less than 10% of the joints. If defects are revealed the extent of examination shall be increased to 100% and shall include inspection of previously accepted welds. This special approval can only be granted if well-documented quality assurance procedures and records are available to enable the Society to assess the ability of the manufacturer to produce satisfactory welds consistently.
- 3) For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests shall be carried out at the discretion of the Society depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes shall be radiographed.

The radiographs shall be assessed according to ISO 5817 "Arc-welded joints in steel - Guidance on quality levels for imperfections", and are at least to meet the requirements for quality level B.

**703** After assembly, all cargo and process piping shall 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 onboard shall be hydrostatically tested to at least 1.5 times 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 methods shall be submitted for approval.

**704** After assembly onboard, each cargo and process piping system shall be subjected to a leak test using air, halides or other suitable medium.

**705** Emergency shut-down valves with actuators shall be function tested when the valve is subjected to full working pressure.

### C 800 Prototype testing

**801** Each type of valve shall be subjected to prototype tests as follows. Each size and each type of valve intended to be used at a working temperature below  $-55^{\circ}\text{C}$  shall be subjected to a tightness test at the minimum design temperature or lower and to a pressure not lower than the design pressure for the valves. During the test the good operation of the valve shall be ascertained.

**802** The following prototype tests shall be performed on each type of expansion bellows intended for use on cargo piping, primarily on those used outside the cargo tank:

- 1) An overpressure test. A type element of the bellows, not precompressed, shall be pressure tested to a pressure not less than 5 times the design pressure without bursting. The duration of the test shall not be less than 5 minutes.
- 2) A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc.) at twice the design pressure at the extreme displacement conditions recommended by the manufacturer. No permanent deformations are allowed. Depending on materials the test may be required to be performed at the minimum design temperature.
- 3) A cyclic test (thermal movements). The test shall be performed on a complete expansion joint, which shall successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rota-

tional movement and transverse movement, as it will encounter in actual service. Testing at room temperature, when conservative, is permitted.

- 4) A cyclic fatigue test (ship deformation). The test shall be performed on a complete expansion joint, without internal pressure, by simulating the bellow movement corresponding to a compensated pipe length for at least  $2 \cdot 10^6$  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.

**803** The Society may waive performance of the tests specified in 802, provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions.

When the maximum internal pressure exceeds 1 bar, this documentation shall include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

## D. Cargo Hoses

### D 100 General

**101** Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.

**102** Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.

**103** Each new type of cargo hose, complete with end fittings, shall be prototype tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the extreme service temperature. Hoses used for prototype testing shall not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced shall be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure but not more than two-fifths its bursting pressure. The hose shall be stencilled or otherwise marked with the date of testing its specified maximum working pressure, and if used in other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 10 bar gauge.

## E. Bow or Stern Loading and Unloading Arrangements

### E 100 General

**101** Subject to the approval of the Society, cargo piping may be arranged to permit bow or stern loading and unloading.

**102** Bow or stern loading and unloading lines which are led past accommodation spaces, service spaces or control stations shall not be used for the transfer of products requiring a type 1G ship. Bow or stern loading and unloading lines shall not be used for the transfer of toxic products unless specifically approved.

**103** Portable arrangements are not permitted.

**104** The following additional provisions apply to such cargo piping and related piping equipment:

- 1) 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 open deck and shall be at least 760 mm inboard except for thwartships 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 is also to be capable of being separated by means of a removable spool piece and blank flanges when not in use.
- 2) The piping shall be full penetration butt welded, and fully radiographed regardless of pipe diameter and design temperature. Flange connections in the piping are only permitted within the cargo area and at the shore connection.
- 3) 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 be blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

**105** Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall be arranged according to Sec.3 C103.

**106** Deck openings and air inlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of bow or stern loading or unloading arrangements.

**107** Electrical equipment within a zone of 3 m from the cargo shore connection location shall be in accordance with Sec.12.

**108** Fire-fighting arrangements for the bow or stern loading and unloading areas shall be in accordance with Sec.11 B201.3 and Sec.11 B307.

**109** Means of communication between the cargo control station and the shore connection location shall be provided and if necessary certified safe.

## F. Vapour Return Connections

### F 100 General

**101** Connections for vapour lines to the shore installation shall be provided.

## G. Certification of Pumps

### G 100 General

**101** Cargo pumps shall be delivered with DNV product certificate and shall be tested as given in Pt.4 Ch.6 Sec.6. Pump housings shall be furnished with material certificates in accordance with Sec.2 Table E1.

**102** For pumps used in the cargo related systems (not being cargo pumps) like pumps for glycol, ethanol and lubrication oil, maker's product certificate will be accepted.

## H. Certification of Valves

### H 100 General

**101** The constructional requirements given in Pt.4 Ch.6 Sec.6 C100 apply as relevant. For valves intended for piping systems with a design temperature below -55°C documentation of leak and functional test at design temperature (prototype test) according to C800 is required.

### H 200 Hydrostatic test and seat leakage test

**201** Valves shall be subjected to the following tests at the manufacturer's:

- hydrostatic test of valve bodies at a pressure equal to 1.5 times the design pressure
- seat and stem seal leakage test at a pressure equal to 1.1 times the design pressure.

### H 300 Certification of valves

**301** DNV product certificate is required for valves with DN > 100 mm. For valves with DN ≤ 100 mm, manufacturer's product certificate may be accepted.

**302** Valves shall be furnished with material certificates in accordance with Sec.2 Table E1.

## SECTION 7

# CARGO PRESSURE AND TEMPERATURE CONTROL, CARGO HEATING ARRANGEMENTS, INSULATION

### A. Cargo Pressure and Temperature Control

#### A 100 General

**101** Unless the entire cargo system is designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, maintenance of the cargo tank pressure below the MARVS shall be provided by one or more of the following means, except as otherwise provided in these rules:

- a system which regulates the pressure in the cargo tanks by the use of mechanical refrigeration
- a system whereby the boil-off vapour is utilised as fuel for shipboard use and or waste heat system subject to the provisions of Sec.16. This system may be used at all times, including while in port and while manoeuvring, provided that a means of disposing of excess energy is provided, such as a steam dump system, that is acceptable to the Society
- a system allowing the product to warm up and increase in pressure. The insulation and or cargo tank design pressure shall be adequate to provide for a suitable margin for the operating time and temperatures involved
- other systems acceptable to the Society.

**102** If cargo cooling is achieved by means of evaporated gas and the gas is not re-liquefied or utilised as fuel for shipboard use, the boil-off gas is normally to be burnt or in other ways rendered harmless before being expelled from the ship.

**103** The systems required by 101 shall be constructed, fitted and tested to the satisfaction of the Society. Materials used in their construction shall be suitable for use with the cargoes to be carried. For normal service, the upper ambient design temperatures shall be:

Sea 32°C  
Air 45°C

For service in especially hot or cold zones, these temperatures will be increased or reduced, as appropriate, by the Society.

**104** Boil-off gas, being re-liquefied or used as boiler or engine fuel, shall be led through valves and pipes independent of the pressure relief valves on tanks. Regarding utilisation of boil-off gas for combustion purposes in boilers or internal combustion engines, see Sec.16.

**Guidance note:**

For LNG Boil-off Re-liquefaction Plants and Gas Combustion Units reference is made to Classification Note 61.2.

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#### A 200 Cargo refrigeration and reliquefaction system

**201** A refrigeration system shall consist of one or more units capable of maintaining the required cargo pressure and temperature under conditions of the upper ambient design temperatures, see 103. Unless an alternative means of controlling the cargo pressure and temperature is provided to the satisfaction of the Society, a stand-by unit (or units) affording spare capacity at least equal to the largest required single unit shall be provided. A stand-by unit shall 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 shall 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.

**202** Where two or more refrigerated cargoes, which may react chemically in a dangerous manner, are carried simultaneously, special consideration shall be given to the refrigeration systems to avoid the possibility of mixing cargoes. For the carriage of such cargoes, separate refrigeration systems, each complete with a stand-by unit as specified in 201, shall be provided for each cargo. However, where cooling is provided by an indirect or combined system (see 207 and 208) and leakage in the heat exchangers cannot cause mixing of the cargoes under any envisaged condition, separate refrigeration units need not be fitted.

**203** When carrying two or more refrigerated cargoes, which are not mutually soluble under the conditions of carriage, so that their vapour pressures would be additive on mixing, special consideration shall be given to the refrigeration systems to avoid the possibility of mixing cargoes.

**204** Where cooling water is required in refrigeration systems, an adequate supply shall be provided by a pump(s) used exclusively for this purpose. This pump(s) shall have at least two sea suction lines, where practicable leading from sea chests one port and one starboard. A spare pump of adequate capacity shall be provided, which may be a pump used for other services so long as its use for cooling would not interfere with any other essential service.

**205** The refrigeration system may be arranged in one of the ways specified in 206 to 208.

**206** A direct system where evaporated cargo is compressed, condensed and returned to the cargo tanks. (For certain cargoes specified in the *List of Cargoes*, this system shall not be used.)

**207** An indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed.

**208** A combined (cascade) system where evaporated cargo is compressed and condensed in a cargo or refrigerant heat exchanger and returned to the cargo tanks. (For certain cargoes specified in the *List of Cargoes*, this system shall not be used.)

**209** All primary and secondary refrigerants must be compatible with each other and with the cargo with which they may come into contact. The heat exchange may take place either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

**210** The cooling system shall comply with the requirements given in Ch.10 to the extent these are applicable.

**Guidance note:**

For LNG Boil-off Re-liquefaction Plants and Gas Combustion Units reference is made to Classification Note 61.2.

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#### A 300 Certification and testing of compressors

**301** Compressors used in the re-liquefaction system shall be certified as given in Pt.4 Ch.5 Sec.4.

### B. Cargo Heating Arrangements

#### B 100 General

**101** Requirements for water systems and steam systems are identical to those of Pt.4 Ch.6 Sec.5, unless otherwise stated.

**102** Normally, the temperature of the heating medium shall not exceed 220°C.

**103** The heating media shall be compatible with the cargo.

**104** For heating of cargoes where gas detection with regard to toxic effects are required by column d in the *List of Cargoes*, the heating medium shall not be returned to the engine room. For heating of other cargoes, the medium may be returned to the engine room provided a degassing tank with gas detector is arranged. The degassing tank shall be located in the cargo area.

## C. Insulation for Tanks, Hold Spaces and Pipelines

### C 100 Insulation

**101** If required, suitable insulation shall be provided to ensure that the hull steel significant temperature does not fall below the minimum allowable steel significant temperature for the concerned grade of steel, as detailed in Sec.2.

**102** In determining the insulation thickness, due regard shall be paid to the amount of acceptable boil-off in association with the cargo pressure and temperature control system as required in A100.

**103** The insulation system shall be suitable for the mechanical and thermal loads imposed on it.

### C 200 Insulating materials

**201** In addition to the requirements in 202 to 205, reference is made to Ch.10, which shall be complied with to the extent applicable.

Organic foams shall be of a flame-retarding quality, i.e. with low ignition point and low flame-spread properties. Testing shall be carried out in accordance with a recognised standard, e.g. DIN 4102 IB2, or equivalent. The test method chosen shall be suitable for the type of foam in question.

**202** Materials used for thermal insulation shall be tested for the following properties as applicable, to ensure that they are adequate for the intended service:

- compatibility with the cargo
- solubility in the cargo
- absorption of the cargo
- shrinkage
- ageing
- closed cell content
- density
- mechanical properties
- thermal expansion
- abrasion
- cohesion
- thermal conductivity
- resistance to vibration
- resistance to fire and flame spread.

**203** In addition to the above requirements insulation materials which contribute as cargo containment as defined in Sec.1 D800 shall be tested for the following properties after simulation of ageing and thermal cycling to ensure that they are ade-

quate for the intended service:

- bonding (adhesive and cohesive strength)
- resistance to cargo pressure
- fatigue and crack propagation properties
- compatibility with cargo constituencies and any other agent expected to be in contact with the insulation in normal service
- where applicable the influence of presence of water and water pressure on the insulation properties shall be taken into account
- gas de-absorbing.

**204** The properties required by 202 or 203 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.

**205** The procedures for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials shall be in accordance with a specification approved by the Society.

### C 300 Fixing and protection of insulating materials

**301** The insulation shall be fixed in place and protected against mechanical damage, moisture, etc. which may reduce its efficiency.

**302** Where applicable, due to location and or environmental conditions, insulation materials shall have suitable properties of fire resistance and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage.

**303** If the temperature in the tanks may drop below 0°C under normal operating conditions, the ship shall be built and equipped in such a way that moisture accumulation in the hold spaces is prevented.

Details of the arrangement to be forwarded in each case.

**304** Insulation on the inner bottom and on the lower part of sides and bulkheads in hold spaces, shall be arranged in such a way that it will not be damaged if condensed water should drip from the tanks.

**305** Where powder or granulated insulation is used, the arrangement shall be such as to prevent compacting of the material due to vibration. The design shall incorporate means to ensure that the material remains sufficiently buoyant to maintain the required thermal conductivity and also prevent any undue increase of pressure on the containment system.

### C 400 Inspection of insulation

**401** The insulation shall be arranged with due regard to access for regular inspections of the insulation itself and of the structures it covers to the extent deemed practicable for the respective cargo containment systems.

### C 500 Non-cooled cargo tanks exposed to sun radiation

#### Guidance note:

Non-cooled cargo tanks exposed to direct sun radiation should preferably have a heat-reflecting surface, for example a light colour.

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## SECTION 8 MARKING OF TANKS, PIPES AND VALVES

### A. General

#### A 100 Application

**101** General requirements regarding marking of valves are given in Pt.4 Ch.6 Sec.3.

### B. Marking

#### B 100 Language

**101** All marking shall be in the language of the registration country of the ship. On ships in international service, corresponding marking is also to be made in a language appropriate for the ship's normal route, preferably in English.

#### B 200 Marking plates

**201** Marking plates shall be made of corrosion-resistant materials, and shall be permanently fixed to valves handles, flanges or similar parts. Markings, bolt holes etc. in the tanks themselves shall be avoided. The lettering shall be impressed on the marking plate in letters of at least 5 mm height. The marking plates shall be placed in easily visible positions and shall not be painted.

#### B 300 Marking of tanks, pipes and valves

**301** Every independent tank shall have a marking plate reading as follows:

- tank no.
- design pressure (bar)
- maximum cargo density (kg/m<sup>3</sup>)
- lowest permissible temperature (°C)
- capacity of the tank (m<sup>3</sup>) (98% filled)
- test pressure (bar)
- name of builder
- year of construction.

The marking plate may also be used for the necessary markings of identification. For definitions of:

- design pressure, see Sec.1 B114.
- test pressure, see Sec.5 N.

**302** All valves shall be clearly marked to indicate where the connected pipelines lead.

#### B 400 Marking of tank connections

**401** All intake and outlet connections, except safety valves, manometers and liquid level indicators, shall be clearly marked to indicate whether the connection leads to the vapour or liquid phase of the tank.

## SECTION 9 GAS-FREEING AND VENTING OF CARGO TANKS AND PIPING SYSTEM

### A. Gas-Freeing

#### A 100 General

**101** Inerting refers to the process of providing a non-combustible environment by the addition of compatible gases, which may be carried in storage vessels or manufactured on board the ship or supplied from the shore. The inert gases shall be compatible chemically and operationally, at all temperatures likely to occur within the spaces to be inerted, with the materials of construction of the spaces and the cargo. The dew points of the gases shall be taken into consideration.

**102** Arrangements suitable for the cargo carried, shall be provided to prevent the back flow of cargo vapour into the inert gas system.

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

**104** Piping from an inert gas plant shall be connected to the cargo piping system or cargo containment system only for inerting or venting purposes and when these systems are at atmospheric pressure.

**105** Permanent pipe connections between an inert gas plant and the cargo piping system or cargo containment system will normally not be accepted.

**106** Where inert gas is stored at temperatures below 0°C, either as a liquid or vapour, the storage and supply system shall be so designed that the temperature of the ship's structure is not reduced below the limiting values imposed on it.

#### A 200 Cargo tanks

**201** A piping system shall be provided to enable each cargo tank to be safely gas-freed and to be safely purged with cargo gas from a gas-free condition. The system shall be arranged to minimise the possibility of pockets of gas or air remaining after gas-freeing or purging.

**202** The ventilating system for cargo tanks shall be used exclusively for tank ventilating purposes.

**203** A sufficient number of gas sampling points shall be provided for each cargo tank in order to adequately monitor the progress of purging and gas-freeing. Gas sampling connections shall be valved and capped above the main deck.

**204** For flammable gases, the system shall be arranged to minimise the possibility of a flammable mixture existing in the cargo tank during any part of the gas-freeing operation utilising an inerting medium as an intermediate step. In addition, the system shall enable the cargo tank to be purged with an inerting medium prior to filling with cargo vapour or liquid without permitting a flammable mixture to exist at any time within the cargo tank.

#### A 300 Cargo piping system

**301** Piping systems which may contain cargo, shall be capable of being gas-freed and purged as provided in 201 and 204.

**302** When a ventilating plant is connected to the cargo lines, the connecting pipe shall have two valves, one of which shall be a non-return valve or a flap valve, and the other a stop valve.

### B. Tank Venting Systems

#### B 100 Definitions

**101** In the following the term "pressure relief valve" denotes a safety valve which opens at a given internal pressure above atmospheric pressure, and the term "vacuum relief valve" denotes a safety valve which opens at a given internal pressure below atmospheric pressure. By P/V valves are meant combined pressure/vacuum relief valves.

#### B 200 Pressure relief systems

**201** All tanks shall have at least two completely independent pressure relief valves when the tank volume is 20 m<sup>3</sup> or greater and at least one pressure relief valve when the tank volume is less than 20 m<sup>3</sup>.

In general, the setting of the pressure relief valves shall not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS.

**202** If two or more pressure relief valves are fitted, the valves shall be of approximately equal capacity.

**203** Pressure relief valves shall be connected to the highest part of the tank above deck level and so that they will remain in the vapour phase under conditions of 15° list and 0.015 L trim at the maximum allowable filling limit (FL) as defined in Sec.17. L is length of ship in m, defined as the distance between perpendiculars.

Pressure relief valves on cargo tanks with a design temperature below 0°C shall be arranged to prevent them from becoming inoperative due to ice formation when they are closed. Due consideration shall be given to the construction and arrangement of pressure relief valves on cargo tanks subject to low ambient temperatures.

Valves shall be constructed of materials with a melting point above 925°C. Consideration of lower melting point materials for internal parts and seals shall be given if their use provides significant improvement to the general operation of the valve.

**204** Pressure relief valves shall be prototype tested for verification of capacity.

Each pressure relief valve is also to be tested for verification of set pressure. The set pressure deviation shall not exceed ±10% for 0 to 1.5 bar, ±6% for 1.5 to 3.0 bar and ±3% for 3.0 bar and above.

The pressure relief valves shall be set and sealed in the presence of a surveyor.

**205** More than one relief valve setting on cargo tanks 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 alternate springs or by other similar means not requiring pressure testing to verify the new set pressure.

#### Guidance note:

The changing of the set pressure under the provisions of 205 and the corresponding resetting of alarms referred to in Sec.13 B501 should be carried out under the supervision of the master in accordance with procedures approved by the Society and specified

in the ship's appendix to the classification certificate. Changes in set pressures should be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

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**206** If stop valves or other means of blanking off pipes are fitted between the tanks and the pressure relief valves, an interlocking mechanism shall be arranged in order to prevent all pressure relief valves for the same tank from being out of service simultaneously.

A device which automatically and in a clearly visible way indicates which of the pressure relief valves is out of service, is also to be fitted. The in service remaining pressure relief valves shall have the combined relieving capacity required by 300. However, this capacity may be provided by all valves if a suitably maintained spare valve is carried onboard.

**207** Each pressure relief valve installed on a cargo tank shall be connected to a venting system which shall be so constructed that the discharge of gas will be unimpeded and directed vertically upwards at the exit and so arranged as to minimise the possibility of water or snow entering the vent system.

**208** The outlets for escape gas from pressure relief valves are normally to be situated at a height not less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above the working area, the fore and aft gangway, deck storage tanks and cargo liquid lines, where B means greatest moulded breadth of the ship in m. The outlets shall be located at a distance at least equal to B or 25 m, whichever is less, from the nearest:

- air intake, air outlet or opening to accommodation, service and control station spaces, or other gas-safe spaces
- exhaust outlet from machinery or from furnace installations onboard.

For ships less than 90 m in length, the Society may accept smaller distances.

**209** All other cargo vent exits not dealt with in other chapters, shall be arranged in accordance with 208.

**210** If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each cargo carried.

**211** In the piping system for escape gas, means for draining condensed water from places where it is liable to accumulate, shall be fitted, preferably in the form of special condensation pots. The pressure relief valves and pipes for escape gas shall be so arranged that condensed water under no circumstances remains accumulated in or near the pressure relief valves.

**212** Suitable protection screens shall be fitted on vent outlets to prevent the ingress of foreign objects.

**213** All pipes for escape gas shall be so arranged that they will not be damaged by temperature variations in the pipes or by the ship's motion in a seaway.

**214** The back pressure in the vent lines from the pressure relief valves shall be taken into account in determining the flow capacity required by 300.

The pressure drop in the vent line from the tank to the pressure relief valve inlet shall not exceed 3% of the valve set pressure. For unbalanced pressure relief valves, the back pressure in the discharge line shall not exceed 10% of the gauge pressure at the relief valve inlet with the vent lines under fire exposure as referred to in 300.

**215** The adequacy of the vent system fitted on tanks loaded in accordance with Sec.17 A106 is demonstrated using the guidelines given in IMO Res. A.829(19) "Guidelines for the evaluation of the adequacy of type C tank vent systems". If the vent system is found acceptable, a "Certificate of increased

loading limit" will be issued by the Society.

For the purpose of this paragraph, vent system means:

- 1) The tank outlet and the piping to the pressure relief valve.
- 2) The pressure relief valve.
- 3) The piping from the pressure relief valve to the location of discharge to the atmosphere and including any interconnections and piping which joins other tanks.

### B 300 Size of valves

**301** Pressure relief valves shall have a combined relieving capacity for each cargo tank to discharge the greater of the following with not more than a 20% rise in cargo tank pressure above the maximum allowable relief valve setting of the cargo tank (MARVS):

- 1) The maximum capacity of the cargo tank inerting system if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks, or
- 2) Vapours generated under fire exposure computed using the following formula:

$$Q = F G A^{0.82} \quad (\text{m}^3/\text{s})$$

- Q = minimum required rate of discharge of air at standard conditions of 273 K and 1.013 bar
- F = fire exposure factor for different cargo tank types
- = 1.0 for independent tanks without insulation located on deck
  - = 0.5 for independent tanks above the deck with insulation. (Acceptance of this value will be based on the use of an approved fire-proofing 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 area above and below deck.

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

- T = temperature in kelvin (K) at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set
- L = latent heat of the product being vapourised at relieving conditions (kJ/kg)
- D = constant based on relation of specific heats (k), shown in Table B1

If k is not known, D = 0.606 should be used. The constant D may also be calculated by the following formula:

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

- Z = compressibility factor of the gas at relieving conditions. If not known, Z = 1.0 should be used.
- M = molecular mass of the product
- A = external surface area of the tank (m<sup>2</sup>). To be calculated

for the different tank types as given below:

For body of revolution type tanks:

A = external surface area

For other than bodies of revolution type tanks:

A = external surface area less the projected bottom surface area

For tanks consisting of an array of pressure vessel tanks:

1) insulation on the ship's structure:

A = external surface area of the hold less its projected bottom area

2) insulation on the tank structure:

A = external surface area of the array of pressure vessels excluding insulation as shown in Fig. 1, less the projected bottom area.

— other vacuum relief systems acceptable to the Society.

<i>k</i>	<i>D</i>	<i>k</i>	<i>D</i>
1.00	0.606	1.52	0.704
1.02	0.611	1.54	0.707
1.04	0.615	1.56	0.710
1.06	0.620	1.58	0.713
1.08	0.624	1.60	0.716
1.10	0.628	1.62	0.719
1.12	0.633	1.64	0.722
1.14	0.637	1.66	0.725
1.16	0.641	1.68	0.728
1.18	0.645	1.70	0.731
1.20	0.649	1.72	0.734
1.22	0.652	1.74	0.736
1.24	0.656	1.76	0.739
1.26	0.660	1.78	0.742
1.28	0.664	1.80	0.745
1.30	0.667	1.82	0.747
1.32	0.671	1.84	0.750
1.34	0.674	1.86	0.752
1.36	0.677	1.88	0.755
1.38	0.681	1.90	0.758
1.40	0.685	1.92	0.760
1.42	0.688	1.94	0.763
1.44	0.691	1.96	0.765
1.46	0.695	1.98	0.767
1.48	0.698	2.00	0.770
1.50	0.701	2.02	0.772
		2.20	0.792

### B 400 Vacuum protection systems

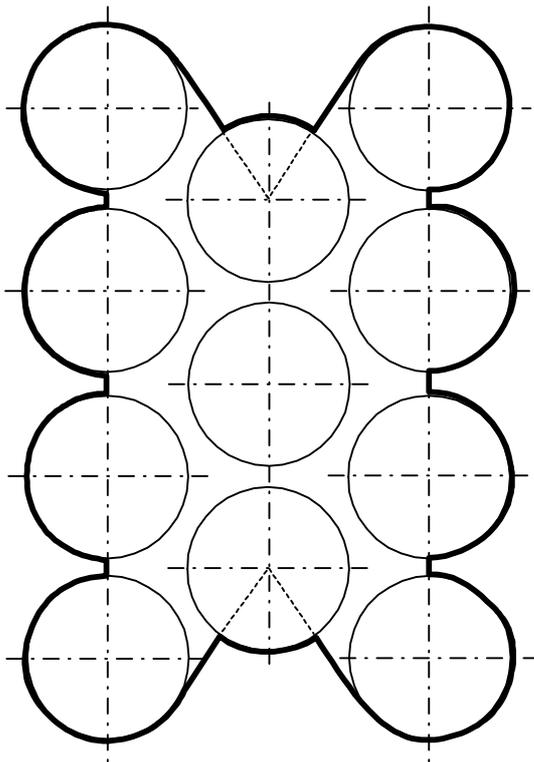
**401** Cargo tanks designed to withstand a maximum external pressure differential exceeding 0.25 bar and capable of withstanding the maximum external differential pressure which can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, need no vacuum relief protection.

**402** Cargo tanks designed to withstand a maximum external pressure differential not exceeding 0.25 bar, or tanks which cannot withstand the maximum external differential pressure that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by sending boil-off vapour to the machinery spaces, shall be fitted with:

- two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank, and refrigeration equipment if fitted, by suitable means at a pressure sufficiently below the external design differential pressure 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 design differential pressure of the cargo tank, or

<i>Product</i>	<i>m = - di / d ρ<sub>r</sub> (kJ / kg)</i>
Ammonia, anhydrous	3 400
Butadiene	1 800
Butane	2 000
Butylenes	1 900
Ethane	2 100
Ethylene	1 500
Methane	2 300
Methyl chloride	816
Nitrogen	400
Propane	2 000
Propylene	1 600
Propylene oxide	1 550
Vinyl chloride	900

The values in this table may be used for set pressures not higher than 2.0 bar.



**Fig. 1**  
**External surface area of the array of pressure vessels**

**403** Subject to relevant requirements of Sec.15, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimise the possibility of the entrance of water or snow. If cargo vapour is admitted, it shall be from a source other than the cargo vapour lines.

**404** The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.

**B 500 Additional pressure relieving system for liquid level control**

**501** Where required by Sec.17 A105.2, 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 300 shall be fitted to each tank. This pressure relieving system shall 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 Sec.17 A105.2 and;
- 2) An override arrangement, whenever necessary, to prevent its normal operation. This arrangement shall include fusible elements designed to melt at temperatures between 98°C and 104°C and to cause relief valves specified in 401.1 to become operable. The fusible elements shall be located, in particular, in the vicinity of relief valves. The system shall become operable upon loss of system power if provided. The override arrangement shall not be dependent on any source of ship's power.

**502** The total relieving capacity of the additional pressure relieving system at the pressure mentioned in 401.1 shall not be less than:

$$Q' = F G' A^{0.82} \quad (\text{m}^3/\text{s})$$

$Q'$  = minimum required rate of discharge of air at standard conditions of 273 K and 1.013 bar

$$G' = \frac{12.4}{(L + \rho_r m) D} \sqrt{\frac{Z T'}{M}}$$

$\rho_r$  = 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 (kJ/kg) at relieving conditions. For set pressures not higher than 2.0 bar the values in Table B2 may be used. For products not listed in the table and for higher set pressures, the value of  $m$  shall be calculated on the basis of the thermodynamic data of the product itself

$i$  = enthalpy of liquid (kJ/kg)

$T'$  = temperature at relieving conditions, i.e. at the pressure at which the additional pressure relieving system is set (K).

$F, A, L, D, Z$  and  $M$  are defined in 300.

**503** Compliance with 401.1 requires changing of the setting of the relief valves provided for in this section. This shall be accomplished in accordance with the provisions of 300.

**504** Relief valves mentioned under 401.1 above may be the same as the pressure relief valves mentioned in 200, provided the setting pressure and the relieving capacity are in compliance with the requirements of this section.

**505** The exhaust of such pressure relief valves may be led to the venting system referred to in 207 and 208. If separate venting arrangements are fitted these shall be in accordance with the requirements of 207 to 214.

**C. Certification of Pressure Relief Valves**

**C 100 General**

**101** Manufacturer's catalogue with specification shall be submitted for information. Pressure relief valves shall have been prototype tested for verification of capacity according to B204.

**C 200 Production testing of each valve**

**201** All new valves shall be subjected to the following tests at the manufacturer:

- hydrostatic test at a pressure equal to 1.5 times the design pressure
- verification of set pressure
- seat leakage test at 90% of the set pressure.

The set pressure shall be sealed by the use of a robust non-corrosive wire.

**C 300 Certification of pressure relief valves**

**301** DNV product certificate is required for all pressure relief valves on cargo tanks. For other pressure relief valves used in the cargo systems, DNV product certificate is required for valves with  $DN > 75$  mm. For valves with  $DN \leq 75$  mm manufacturer's product certificate may be accepted.

**302** The safety relief valves shall be furnished with material certificates in accordance with Sec.2 Table E1.

## SECTION 10 MECHANICAL VENTILATION IN CARGO AREA

### A. System Requirements

#### A 100 General

**101** Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces. Ventilation systems within the cargo area shall be independent of other ventilation systems.

**102** Air inlets for hazardous enclosed spaces shall be taken from areas which, in the absence of the considered inlet, would be non-hazardous.

Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area.

Where the inlet duct passes through a more hazardous space, the duct shall have over-pressure relative to this space, unless mechanical integrity and gas-tightness of the duct will ensure that gases will not leak into it.

**103** Air outlets from non-hazardous spaces shall be located outside hazardous areas.

**104** Air outlets from hazardous enclosed spaces 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.

**105** Ventilation ducts for spaces within the cargo area shall not be led through non-hazardous spaces. For exceptions, see Sec.16.

**106** Where mechanical ventilation is required, non-hazardous enclosed spaces shall be arranged with ventilation of the overpressure type while hazardous spaces shall have ventilation with underpressure relative to the adjacent less hazardous spaces.

**107** Wire mesh screens of not more than 13 mm square mesh shall be fitted in outside openings of ventilation ducts. For ducts where fans are installed, protection screens are also to be fitted inside of the fan to prevent the entrance of objects into the fan housing.

**108** Spare parts shall be carried for each type of fan referred to in this section. Normally one motor and one impeller is required carried on board for each type of fan serving cargo handling spaces, unless there is a stand-by fan. For spaces served by more than one fan, wear parts for motor and impeller is considered sufficient.

#### A 200 Fans serving hazardous spaces

**201** Electric fan motors shall not be installed in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

**202** Starters for fans for ventilation of non-hazardous spaces, shall be located outside the cargo area or on open deck.

If electric motors are installed in such rooms, the ventilation capacity shall be great enough to prevent the temperature limits specified in Pt.4 Ch.8, from being exceeded, taking into account the heat generated by the electric motors.

**203** Fans shall be designed with the least possible risk for spark generation.

**204** Minimum safety clearances between the casing and rotating parts shall be such as to prevent any friction with each other.

In no case is the radial air gap between the impeller and the casing to be less than 0.1 times the diameter of the impeller shaft in way of the bearing but not less than 2 mm. It need not

be more than 13 mm.

**205** The parts of the rotating body and of the casing shall be made of materials which are recognised as being spark proof, and they shall have antistatic properties.

Furthermore, the installation on board of the ventilation units shall be such as to ensure the safe bonding to the hull of the units themselves. Resistance between any point on the surface of the unit and the hull, shall not be greater than  $10^6$  ohm.

The following combinations of materials and clearances used in way of the impeller and duct are considered to be non-sparking:

- impellers and or housings of non-metallic material, due regard being paid to the elimination of static electricity
- impellers and housings of non-ferrous metals
- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing,
- impellers and housing of austenitic stainless steel
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

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

### B. Ventilation Arrangement and Capacity Requirements

#### B 100 General

**101** The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

#### B 200 Non-hazardous spaces

**201** Spaces with opening to a hazardous area, shall be arranged with an air-lock, and be maintained at overpressure, relative to the external hazardous area.

The overpressure ventilation shall be arranged according to the following requirements:

- 1) During initial start-up or after loss of overpressure ventilation, it is required before energising any electrical installations not certified safe for the space in the absence of pressurisation, to:
  - proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous, and
  - pressurise the space.
- 2) Operation of the overpressure ventilation shall be monitored.
- 3) In the event of failure of the overpressure ventilation:
  - an audible and visual alarm shall be given at a manned location
  - if overpressure cannot be immediately restored, auto-

matic or programmed disconnection of electrical installations is required according to IEC 60092-502, Table 5.

### **B 300 Cargo handling spaces**

**301** *Cargo handling spaces* are pump rooms, compressor rooms and other enclosed spaces which contain cargo handling equipment and similar spaces in which work is performed on the cargo.

**302** A permanent mechanical ventilation system shall be installed capable of circulating sufficient air to give at least 30 air changes per hour. Ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid the accumulation of vapours and to ensure a safe working environment.

**303** The ventilation systems shall permit extraction from either the upper and lower parts of the spaces, or from both the upper and lower parts, depending on the density of the vapours of the products carried.

**304** The exhaust outlets, which shall discharge upwards, shall be situated at least 4 m above deck and at least 10 m in the horizontal direction from ventilation inlets and other openings to accommodation, service and control station spaces and other non-hazardous spaces.

**305** Ventilation systems for pump and compressor rooms shall be in operation when pumps or compressors are working. Pumps and compressors shall not be started before the ventilation system in the electric motor room has been in operation for 15 minutes. Warning notices to this effect shall be placed in an easily visible position near the control stand.

**306** When the space is dependent on ventilation for its area classification, the following requirements apply:

- 1) During initial start-up, and after loss of ventilation, the space shall be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation.
- 2) Operation of the ventilation shall be monitored.
- 3) In the event of failure of ventilation, the following requirements apply;
  - an audible and visual alarm shall be given at a manned location

- immediate action shall be taken to restore ventilation
- electrical installations shall be disconnected if ventilation cannot be restored for an extended period. The disconnection shall be made outside the hazardous areas, and be protected against unauthorised re-connection, e.g. by lockable switches.

#### **Guidance note:**

Intrinsically safe equipment suitable for Zone 0, is not required to be switched off. Certified flameproof lighting, may have a separate switch-off circuit.

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### **B 400 Other hazardous spaces normally entered**

**401** Air lock spaces shall be mechanically ventilated at an overpressure relative to the adjacent open deck hazardous area.

**402** Other spaces situated on or above cargo deck level (e.g. Cargo Handling Gear lockers) may be accepted with natural ventilation only.

### **B 500 Spaces**

**501** Spaces not normally entered are cofferdams, double bottoms, duct keels, pipe tunnels, spaces containing cargo tanks and other spaces where cargo may accumulate.

**502** A mechanical ventilation system (permanent or portable) shall be provided capable of circulating sufficient air to the compartments concerned. The capacity of the ventilation system is normally to give at least 8 air changes per hour. For hold spaces containing independent tanks a lower capacity may be accepted, provided it can be demonstrated that the space concerned can be satisfactorily gas-freed in less than 5 hours. For inerted spaces an increase of the oxygen content from 0% to 20% in all locations of the space within 5 hours would be acceptable.

**503** Ducting shall be fitted, if necessary, to ensure efficient gas-freeing.

**504** Fans shall be installed clear of access openings.

### **B 600 Certification of fans**

**601** Fans and portable ventilators covered by this section shall be delivered with a DNV product certificate. Manufacturer's certificate will be accepted for type approved fans.

## SECTION 11 FIRE PROTECTION AND EXTINCTION

### A. General

#### A 100 Application

**101** The fire safety measures in SOLAS related to tankers in general, will apply depending on flag state authorisation, as specified in Ch.3 Sec.7 A100.

**102** Fire safety measures applicable to gas tankers are specified in B below and in Sec.6 E.

#### A 200 Firefighter's outfit

**201** All ships shall be provided with at least two firefighter's outfits complying with Ch.3 of Fire Safety Systems Code as defined in Pt.4 Ch.10.

In ships carrying flammable products of a cargo capacity of less than 5 000 m<sup>3</sup> two additional firefighter's outfits shall be provided and on ships of a cargo capacity of 5 000 m<sup>3</sup> and over three additional firefighter's outfits shall be provided.

**202** Additional requirements for safety equipment are given in Sec.19.

### B. Fire Extinction

#### B 100 Fire water main equipment

**101** All ships, irrespective of size, carrying products which are subject to this chapter must comply with requirements to fire pumps, fire main, hydrants and hoses in SOLAS Reg. II-2/10.2 for ships above 2 000 gross tonnage, except that the required fire pumps capacity and fire main and water service pipe diameter shall not be limited when the fire pump and fire main are used as part of the water spray system.

In addition, the requirement to minimum pressure at hydrants shall be 5.0 bar.

**102** The arrangement shall be such that at least 2 jets of water not emanating from the same hydrant, one of which shall be from a single length of hose can reach any part of the deck in the cargo area and those portions of the cargo containment systems and tank covers above the deck. Hose lengths shall not exceed 33 m.

**103** Stop valves shall be fitted in any crossover provided and in the fire main or mains at the poop front and at intervals of not more than 40 m between hydrants on the deck in the cargo area for the purpose of isolating damaged sections of the main.

**104** All water nozzles provided for fire-fighting use shall be of an approved dual-purpose type capable of producing either a spray or a jet. All pipes, valves, nozzles and other fittings in the fire fighting systems shall be resistant to the effect of fire and corrosion by seawater, for example by use of galvanised pipe.

**105** Where the ship's engine room is unattended, arrangements shall be made to start and connect to the fire main at least one fire pump by remote control from the bridge or other control station outside the cargo area.

#### B 200 Water spray system

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

- 1) Exposed cargo tank domes and exposed parts of cargo tanks.

- 2) Exposed on-deck storage vessels for flammable or toxic products.
- 3) Cargo liquid and vapour discharge and loading manifolds and the area of their control valves and any other areas where essential control valves are situated and which shall be at least equal to the area of the drip trays provided.
- 4) Boundaries of superstructures, deckhouses normally manned, cargo compressor rooms, cargo pump rooms, store rooms containing high fire risk items and cargo control rooms facing the cargo area. Boundaries of unmanned forecastle structures not containing high fire risk items or equipment, do not require water spray protection.

**202** The system shall be capable of covering all areas mentioned in 201 with a uniformly distributed water spray of at least 10 l/m<sup>2</sup> per minute for horizontal projected surfaces and 4 l/m<sup>2</sup> per minute for vertical surfaces. For structures having no clearly defined horizontal or vertical surfaces, the capacity of the water spray system shall be determined by the greater of the following:

- projected horizontal surface multiplied by 10 l/m<sup>2</sup> per minute; or
- actual surface multiplied by 4 l/m<sup>2</sup> per minute.

On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted at intervals in the spray main for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections which may be operated independently provided the necessary controls are located together, aft of the cargo area. A section protecting any area included in 201, items 1 and 2, shall cover the whole of the athwartship tank grouping which includes that area.

**203** The capacity of the water spray pump shall be sufficient to deliver the required amount of water to all areas simultaneously or, where the system is divided into sections, the arrangements and capacity shall be such as to simultaneously supply water to any one section and to the surfaces specified in 201, items 3 and 4. Alternatively, the main fire pumps may be used for this service, provided that their total capacity is increased by the amount needed for the spray system. In either case, a connection through a stop valve shall be made between the fire main and water spray main outside the cargo area.

**204** Water pumps normally used for other services, may be arranged to supply the water spray main.

**205** The pipes, valves, nozzles and other fittings in the water spray system shall be resistant to corrosion by seawater, for example by galvanised pipe, and to the effect of fire.

**206** Remote starting of pumps supplying the water spray system and remote operation of any normally closed valves in the system should 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 areas protected.

#### Guidance note:

Water spray pipes should be provided with drain holes at the lowest points.

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#### B 300 Dry chemical powder fire extinguishing system

**301** Ships intended to carry flammable products shall be fitted with a fixed dry chemical powder type extinguishing system for the purpose of fighting fire on the deck in the complete cargo area and bow or stern cargo handling areas, if applicable.

The system shall be of approved type and tested for its purpose.

**302** The system shall be capable of delivering powder from at least two hand hose lines or a combination monitor and hand hose line(s) to any part of the above-deck exposed cargo area including above-deck product piping.

The system shall be activated by an inert gas, such as nitrogen, used exclusively for this purpose and stored in pressure vessels adjacent to the powder containers.

**303** The system shall consist of at least two independent, self-contained dry chemical powder units with associated controls, pressurising medium, fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1 000 m<sup>3</sup>, consideration may be given to permit only one such unit to be fitted. A monitor shall be provided and so arranged as to protect the cargo loading and discharge manifold areas and be capable of actuation and discharge 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. All hand hose lines and monitors shall be capable of actuation at the hose storage reel or monitor. At least one hand hose line or monitor shall be situated at the after end of the cargo-area.

**304** A fire-extinguishing unit having two or more monitors, hand hose lines, or combinations thereof, shall have independent pipes with a manifold at the powder container. Where two or more pipes are attached to a unit the arrangement shall be such that any or all of the monitors and hand hose lines shall be capable of simultaneous or sequential operation at their rated capacities.

**305** The capacity of a monitor shall not be 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 be such as to allow operation by one man. The length of a hand hose line shall not exceed 33 m. 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 fluidised state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather-resistant housing or covers and be readily accessible.

**306** A sufficient quantity of dry chemical powder shall be stored in each container to provide a minimum 45 s discharge time for all monitors and hand hose lines attached to each powder unit. Coverage from fixed monitors shall be in accordance with the following requirements:

Capacity of fixed monitors (kg/s) each	10	25	45
Maximum distance of coverage (m)	10	30	40

Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration shall be given where areas to be protected are substantially higher than the monitor or hand hose reel locations.

**307** Ships fitted with bow or stern loading and discharge arrangements, shall be provided with an additional dry chemical powder unit complete with at least one monitor and one hand hose line. This additional unit shall be located to protect the bow or stern loading and discharge arrangements. The area of the cargo line forward or aft of the cargo area shall be protected by hand hose lines.

#### **B 400 Cargo compressor and pump-rooms**

**401** The cargo compressor and pump-rooms of any ship shall be provided with carbon dioxide system as specified in Ch.5 of Fire Safety Systems Code as defined in Pt.4 Ch.10. A notice shall be exhibited at the controls stating that the system is only to be used for fire extinguishing and not for inerting purposes, due to the electrostatic ignition hazard. The alarms referred to in Ch.5 of Fire Safety Systems Code as defined in Pt.4 Ch.10 shall be safe for use in a flammable cargo vapour-air mixture. For the purpose of this requirement, an extinguishing system shall be provided which is suitable for machinery spaces. However, the amount of carbon dioxide gas carried shall be sufficient to provide a quantity of free gas equal to 45% of the gross volume of the cargo compressor and pump-rooms in all cases.

**402** Cargo compressor and pump-rooms of ships which are dedicated to the carriage of a restricted number of cargoes shall be protected by an appropriate fire extinguishing system approved by the Society.

## SECTION 12

# AREA CLASSIFICATION AND ELECTRICAL INSTALLATIONS

### A. General

#### A 100 Application

**101** The requirements in this chapter are additional to those given in Pt.4 Ch.8 and apply to tankers with the additional class notation **Tanker for Liquefied Gas**. The requirements may be made wholly or partly valid also for tankers for other cargoes (**Tanker for C**) in some cases.

Relaxation from these rules may be accepted for ships built to carry only non-flammable products.

### B. Electrical Installations in Cargo Area and Adjacent to this Area

#### B 100 General

**101** Electrical equipment and wiring are in general not to be installed in hazardous areas unless essential for operational purposes. The type of equipment and installation requirements shall comply with Pt.4 Ch.8 Sec.11 according to the area classification as specified in C.

In addition, installations as specified in 102 are accepted.

#### **102** In Zone 1:

Impressed cathodic protection equipment is accepted provided the following is complied with:

- such equipment shall be of gas-tight construction or be housed in a gas tight enclosure
- cables shall be installed in steel pipes with gas-tight joints up to the upper deck
- corrosion resistant pipes, providing adequate mechanical protection, shall be used in compartments which may be filled with seawater (e.g. permanent ballast tanks)
- wall thickness of the pipes shall be as for overflow and sounding pipes through ballast or fuel tanks, in accordance with Pt.4 Ch.6 Sec.6.

#### *In Zone 0:*

Submersible electrically driven pumps are accepted provided the following is complied with:

- at least two independent means of shutting down automatically in the event of low liquid level, and prevention from being energised when not submerged
- the supply circuit to the pumps shall be automatically disconnected and/or shall be prevented from being energised in the event of an abnormally low level of insulation resistance or high level of leakage current
- the protective systems shall be arranged so that manual intervention is necessary for the reconnection of the circuit after disconnection after a short circuit, overload or earth-fault condition.

**103** Additional requirements may apply for certain cargoes according to IGC Code Ch.17 and Ch.19.

### C. Area Classification

#### C 100 General

**101** Area classification is a method of analyzing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of elec-

trical apparatus able to be operated safely in these areas.

**102** In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2 according to the principles of the standards IEC 60079-10 and guidance and informative examples given in IEC 60092-502. Main features of the guidance is given in 200-400.

**103** Areas and spaces other than those classified in 200 and 300, shall be subject to special consideration. The principles of the IEC standards shall be applied.

**104** Area classification of a space may be dependent of ventilation as specified in IEC 60092-502, Table I. Requirements to such ventilation are given in Sec.10 B304 to B306.

**105** A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure. Requirements to such pressurisation are given in Sec.10 B201 to B205.

**106** Ventilation ducts shall have the same area classification as the ventilated space.

#### C 200 Tankers for carriage of products with flashpoint not exceeding 60°C

##### 201 Hazardous areas Zone 0

The interiors of cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases or vapours.

##### **Guidance note:**

Instrumentation and electrical apparatus in contact with the gas or liquid should be of a type suitable for zone 0. Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber should be of intrinsically safe type Ex-ia.

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##### 202 Hazardous areas Zone 1

- 1) Void spaces adjacent to, above and below integral cargo tanks.
- 2) Hold spaces containing independent cargo tanks.
- 3) Cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks.
- 4) Cargo compressor room arranged with ventilation according to Sec.10 B305.
- 5) Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tanks bulkheads, unless protected by a diagonal plate acceptable to the appropriate authority.
- 6) Spaces, other than cofferdam, adjacent to a cargo tank boundary or a secondary barrier (for example, trunks, passageways and hold).
- 7) Areas on open deck, or semi- enclosed spaces on deck, within 3 m of any cargo tank outlet, gas or vapour outlet (see note), cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation.

##### **Guidance note:**

Such areas are, for example, all areas within 3 m of cargo tank

hatches, sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

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- 8) Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of liquefied gas or large volumes of vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet.
- 9) Areas on:
  - open deck or semi-enclosed spaces on deck, within 1.5 m of cargo pump room entrances,
  - cargo pump room ventilation inlet,
  - openings into cofferdams or other zone 1 spaces.
- 10) Areas on the open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck.
- 11) Areas where structures are obstructing the natural ventilation e.g. by semi-enclosed spaces, up to a height of 2.4 m above the deck and structure. This applies to:
  - areas in the cargo area on open deck (including also areas above ballast tanks within the cargo area),
  - to the full breadth of the ship,
  - 3 m fore and aft of the forward-most and after-most cargo tank bulkhead.
- 12) Compartments for cargo hoses.
- 13) Enclosed or semi-enclosed spaces in which pipes containing cargoes are located.

### 203 Hazardous areas Zone 2

- 1) Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified in 202, if not otherwise specified in this standard.
- 2) Spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in 202 8).
- 3) The spaces forming an air-lock as defined in Sec.1 B102 and Sec.3 D105 and 106.
- 4) Areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above deck.
- 5) Areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1
- 6) Spaces forward of the open deck areas to which reference is made in 202 11) and 203 5), below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:
  - the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 10 m horizontally from any cargo tank outlet or gas or vapour outlet; and
  - the spaces are mechanically ventilated.

## D. Inspection and testing

### D 100 General

**101** Before the electrical installations in hazardous areas are put into service or considered ready for use, they shall be inspected and tested. All equipment, cables, etc. shall be verified to have been installed in accordance with installations procedures and guidelines issued by the manufacturer of the equipment, cables, etc., and that the installations have been carried out in accordance to Pt.4 Ch.8 Sec.11.

**102** For spaces protected by pressurisation it shall be examined and tested that the purging can be effected. Purge time at minimum flow rate shall be documented. Required shutdowns and / or alarms upon ventilation overpressure falling below prescribed values shall be tested.

For other spaces where area classification depends on mechanical ventilation it shall be tested that ventilation flow rate is sufficient, and that and required ventilation failure alarm operates correctly.

**103** For equipment for which safety in hazardous areas depends upon correct operation of protective devices (for example overload protection relays) and / or operation of an alarm (for example loss of pressurisation for an Ex(p) control panel) it shall be verified that the devices have correct settings and / or correct operation of alarms.

**104** Where interlocking and shutdown arrangements are required (such as for submerged cargo pumps), they shall be tested.

**105** Intrinsically safe circuits shall be verified to ensure that the equipment and wiring are correctly installed.

**106** Verification of the physical installation shall be documented by yard. The documentation shall be available for the Society's surveyor at the site.

## E. Maintenance

### E 100 General

**101** The maintenance manual referred to in Sec.1 C205, shall be in accordance with the recommendations in IEC 60079-17 and 60092-502 and shall contain necessary information on:

- overview of classification of hazardous areas, with information about gas groups and temperature class
- records sufficient to enable the certified safe equipment to be maintained in accordance with its type of protection (list and location of equipment, technical information, manufacturer's instructions, spares etc.)
- inspection routines with information about detailing level and time intervals between the inspections, acceptance/rejection criteria
- register of inspections, with information about date of inspections and name(s) of person(s) who carried out the inspection and maintenance work.

**102** Updated documentation and maintenance manual, shall be kept onboard, with records of date and names of companies and persons who have carried out inspections and maintenance.

Inspection and maintenance of installations shall be carried out only by experienced personnel whose training has included instruction on the various types of protection of apparatus and installation practices to be found on the vessel. Appropriate refresher training shall be given to such personnel on a regular basis.

## F. Signboards

### F 100 General

**101** Where electric lighting is provided for spaces in hazardous areas, a signboard at least 200 x 300 mm shall be fitted at each entrance to such spaces with text:

**BEFORE A LIGHTING FITTING IS OPENED ITS SUPPLY CIRCUIT SHALL BE DISCONNECTED**

Alternatively a signboard with the same text can be fitted at each individual lighting fitting.

**102** Where electric lighting is provided in spaces where the ventilation must be in operation before the electric power is connected, a signboard at least 200 x 300 mm shall be fitted at each entrance, and with a smaller signboard at the switch for each lighting circuit, with text:

**BEFORE THE LIGHTING IS TURNED ON THE VENTILATION MUST BE IN OPERATION**

**103** Where socket-outlets are installed in cargo area or adjacent area, a signboard shall be fitted at each socket-outlet with text:

**PORTABLE ELECTRICAL EQUIPMENT SUPPLIED BY FLEXIBLE CABLES SHALL NOT BE USED IN AREAS WHERE THERE IS GAS DANGER**

Alternatively signboards of size approximately 600 x 400 mm, with letters of height approximately 30 mm, can be fitted at each end of the tank deck.

**104** Where socket-outlets for welding apparatus are installed in areas adjacent cargo area, the socket outlet shall be provided with a signboard with text:

**WELDING APPARATUS NOT TO BE USED UNLESS THE WORKING SPACE AND ADJACENT SPACES ARE GAS-FREE.**

**105** For electrical installations in the cargo area, a warning signboard should be fitted with text:

**WARNING: THIS PANEL DOES CONTAIN ELECTRICAL EQUIPMENT. ANY SERVICING MUST BE UNDERTAKEN ONLY BY QUALIFIED PERSONNEL AND WITH THE POWER SUPPLY DISCONNECTED.**

## SECTION 13 INSTRUMENTATION AND AUTOMATION

### A. General Requirements

#### A 100 General

**101** For instrumentation and automation, including computer based control and monitoring, the requirements in this chapter are additional to those given in Pt.4 Ch.9.

The control and monitoring systems shall be certified according to Pt.4 Ch.9 for the following:

- cargo tank level measurement system
- cargo tank overflow protection system
- cargo valves and pumps control and monitoring system
- flammable gas detection system (permanent system only)
- inert gas control and monitoring system
- cargo and vapour pressure control and monitoring system
- oxygen indication equipment (permanent system only).

**102** Remote reading systems for cargo temperature and pressure shall not allow the cargo or vapour to reach gas-safe spaces. Direct pipe connections will not be accepted.

**103** If the loading and unloading of the ship are performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank shall be concentrated in one control position.

**104** Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid-tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall be appropriate gas detecting devices according to B300. 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.

**105** Instruments shall be tested to ensure reliability in the working conditions and recalibrated at regular intervals. Testing procedures for instruments and the intervals between recalibration shall be approved by the Society.

**106** Where components in remote control systems are required to be designed with redundancy, or to be independent of each other, e.g. gas compressors and cargo pumps, redundancy or independence has also to be provided for in the control system.

### B. Indicating and Alarm Systems

#### B 100 Cargo tank level gauging

**101** By *gauging device* is meant an arrangement for determining the amount of cargo in tanks. Consideration of the hazard and physical properties of each cargo will give the base for selecting one of the types defined in 102 to 108:

**102** Indirect devices, which determine the amount of cargo by means such as weighing or pipe flow meters.

**103** Closed devices, which do not penetrate the cargo tank, such as devices using radio isotopes or ultrasonic devices.

**104** Closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If a closed gauging device is not mounted directly on the tank, it shall be provided with a shut-off valve located as close as possible to the tank.

**105** Restricted devices, which penetrate the tank, and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1.5 mm or equivalent area, unless the device is provided with an excess flow valve.

**106** Types of gauging for individual cargoes shall be in accordance with the requirement in column (c) in the *List of Cargoes*.

**107** Each cargo tank shall be fitted with at least one liquid level gauging device, designed to operate within the allowable tank pressure and temperature range. Where only one liquid level gauge is fitted, it shall be arranged so that any necessary maintenance can be carried out while the cargo tank is in service.

**108** Tubular gauge glasses shall not be fitted. Gauge glasses of the robust type as fitted on high pressure boilers and fitted with excess flow valves, may be allowed for deck tanks.

**109** Sighting ports with a suitable protective cover and situated above the liquid level with an internal scale, may be accepted as a secondary means of gauging for cargo tanks which are designed for a pressure not higher than 0.7 bar.

#### B 200 Overflow control

**201** Cargo tanks shall be equipped with high-level alarm, which is released when the tank is filled up to about 95% of the tank volume. The alarm shall be activated by a level sensing device independent of the level gauging device required in 107.

**202** A level sensing device shall be provided which automatically actuates the shut-off of the flow of cargo to the tank in a manner which will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full. This level sensing device shall be independent of the one which activates the high level alarm required by 201.

The emergency shutdown valve referred to in Sec.6 C305, C306 or C308 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in Sec.6 C309 shall be available on board.

#### Guidance note:

During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, the Administration and the port State Authority may agree to alternative arrangements such as limiting the loading rate, etc.

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**203** A high liquid level alarm and automatic shut-off of cargo tank filling need not be installed when the cargo tank is either:

- a pressure tank with a volume of not more than 200 m<sup>3</sup>, or
- designed to withstand the maximum possible pressure during the loading operation, and such pressure is below that of the set pressure of the cargo tank relief valve.

**204** When pumps situated in different tanks discharge into a common header, stop of the pumps shall be alarmed at the centralized cargo control position.

**205** Electrical circuits, if any, of level alarms shall be capable of being tested prior to loading.

### **B 300 Vapour contents indication and alarm**

**301** Gas detection equipment suitable for the gases to be carried, shall be provided in accordance with column (d) of the *List of Cargoes*.

**302** A permanently installed system of gas detection equipped with audible and visual alarms shall be provided for:

- cargo pump rooms
- cargo compressor rooms
- motor rooms for cargo handling machinery
- cargo control rooms unless designated as gas-safe
- other enclosed spaces in the cargo area where cargo vapour may accumulate including hold spaces and interbarrier spaces
- ventilation hoods and gas ducts where required by Sec.16
- air locks
- degassing tank for cargo heating medium if fitted. See Sec.7 B104.

**303** In the case of products which are toxic or toxic and flammable, the use of portable equipment may be accepted, except when column (f) in the *List of Cargoes* refers to Sec.15 A1000, for toxic detection as an alternative to a permanently installed system. In such cases, a permanently installed piping system for obtaining gas samples from the spaces shall be fitted.

**304** For the spaces listed in 302, alarms shall be activated for flammable products before the vapour concentration reaches 30% of the lower flammable limit. Except for spaces as specified in 305, gas detection instruments for flammable products capable of measuring gas concentrations below the lower flammable limit may be accepted.

**305** In the case of flammable products, where cargo containment systems other than independent tanks are used, hold spaces and/or interbarrier spaces shall be provided with a permanently installed system of gas detection capable of measuring gas concentrations of 0 to 100% by volume. Alarms shall be activated before the vapour concentration reaches the equivalent of 30% of the lower flammable limit in air, or such other limits as may be approved in the light of particular cargo containment arrangements.

**306** Audible and visual alarms from the gas detection equipment, if required by this section, shall be located on the bridge, in the cargo control position required by A102 and at the gas detector readout location.

**307** The gas detection equipment shall be capable of sampling and analyzing from each sampling head location sequentially at intervals not exceeding 30 minutes, except that in the case of gas detection for the hoods and gas ducts where required by Sec.16, sampling shall be continuous. Separate sampling lines to the detection equipment shall be provided.

**308** The suction capacity for every suction period and every suction point shall be sufficient to secure effectively that the gas is analyzed in the same period as it is drawn into the system.

**309** Gas detection equipment shall be so designed that it may readily be tested and calibrated. Testing and calibration shall be carried out at regular intervals. Suitable span gas for the products carried shall be available onboard.

Where practicable, permanent connections for such equipment should be fitted.

**310** In every installation the positions of fixed sampling points shall be determined with due regard to the density of the vapours of the products intended to be carried and the dilution resulting from compartment purging or ventilation.

**311** Pipe runs from sampling heads shall not be led through gas-safe spaces except as permitted by 312.

**312** Gas detection equipment may be located in the cargo control position required by A102, on the bridge or at other

suitable location. When located in a gas-safe space, the following conditions shall be met:

- 1) Sampling lines shall not run through gas safe spaces, except where permitted under sub item 5 below.
- 2) The gas sampling pipes shall be equipped with flame arresters of an approved type. The flame arresters shall be located in safe area, either inside or outside the gas detection unit. Sample gas shall be led to the atmosphere with outlets arranged in a safe location.
- 3) Bulkhead penetrations of sample pipes between safe and dangerous areas shall be of approved type and have the same fire integrity as the division penetrated. A manual isolating valve shall be fitted in each of the sampling lines at the bulkhead on the gas safe side.
- 4) The gas detection equipment including sample piping, sample pumps, solenoids, gas detection sensors etc. shall be located in a reasonably gas tight enclosure (e.g. a fully enclosed steel cabinet with a gasketed door) which shall be monitored by its own sampling point. At gas concentrations above 30% of lower flammable limit inside the enclosure an alarm shall be issued, and the electrical equipment not being of certified safe type shall be automatically de-energised.
- 5) Where the enclosure cannot be arranged directly on the bulkhead facing the gas dangerous space or zone, sample pipes in safe areas outside the cabinet shall be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and gas detection units, and be routed in the shortest way possible.

**313** Two sets of portable gas detection equipment suitable for the products carried shall be provided.

**314** A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.

### **B 400 Temperature indication and alarm**

**401** Each cargo tank shall 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 shall be marked to show the lowest temperature for which the cargo tank has been approved.

**402** When cargo is carried in a cargo containment system with a secondary barrier at a temperature lower than -55°C, temperature sensors shall be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals, and, where applicable, audible warning of temperatures approaching the lowest for which the hull steel is suitable.

**403** If cargo shall be carried at temperatures lower than -55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, shall be fitted with temperature indicating devices as follows:

- a sufficient number of sensors to establish that an unsatisfactory temperature gradient does not occur
- on one tank a number of devices in excess of those required above in order to verify that the initial cool-down procedure is satisfactory. The devices may be either temporary or permanent. When a series of similar ships is built, the second and successive ships need not comply with these requirements.

### **B 500 Pressure indication and alarm**

**501** Each tank shall be provided with at least one local indicating instrument for pressure on each tank and remote pressure indication in the cargo control position required by A102. The manometers and indicators shall be clearly marked with

the highest and lowest pressure permitted in the tank.

In addition a high pressure alarm and, if vacuum protection is required, a low pressure alarm shall be provided on the bridge.

The alarms shall be activated before the set pressures are reached. For cargo tanks fitted with pressure relief valves, which can be set at more than one set pressure in accordance with Sec.9 B205, high-pressure alarms shall be provided for each set pressure.

**502** Manometers shall be fitted to cargo pump discharge lines and to the main loading and discharge vapour and liquid lines.

**503** Local reading manifold pressure gauges shall be provided to indicate the pressure between stop valves and connections to the shore.

**504** Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure gauges.

**B 600 Hold leakage alarm**

**601** A device shall be provided in each hold space surrounding independent cargo tanks for giving alarm in case of leakage of water, oil or cargo into the holds.

## SECTION 14 TESTS AFTER INSTALLATION

### A. General Requirements

#### A 100 General

**101** All systems covered by this chapter shall be tested in operation. As far as practicable, these tests shall be performed at the building yard.

**102** Function tests and capacity tests, which cannot be carried out without a full load of cargo on board, may be carried out in connection with the first cargo loading or transport with a representative cargo.

**Guidance note:**

For LNG Carriers the performance of the cargo system should be verified during first loading and discharging, ref. IGC Code 4.10.14 and IACS Unified Interpretation GC 13 (Jan 2008) "Examination before and after the first loaded voyage".

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**103** Ships equipped with reliquefaction or refrigeration plant, which:

- is designed for maintaining the cargo at a pressure below the tank design pressure, or
- is designed for keeping the cargo at a specified condition at port of discharging, or
- is important to safeguard the quality of cargo, or
- is important for the safety,

shall be tested to demonstrate that the capacity of the plant is sufficient at design conditions.

**Guidance note:**

This test may be performed during a loaded voyage while observing necessary parameters as compressor running time and work-

ing conditions, cargo temperature, air and seawater temperature, etc.

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**104** Heating arrangements, if fitted in accordance with Sec.2 B601, shall be tested for heat output and heat distribution.

**105** Function tests and capacity tests shall be carried out according to a test programme set up by the builder and approved by the Society.

**106** If applicable for the cargo containment system concerned, the hull shall be inspected for cold spots following the first loaded voyage.

#### A 200 Secondary barrier testing requirements

**201** For containment systems with glued secondary barriers:

- a tightness test should be carried out in accordance with approved system designers' procedures before and after initial cool down
- if significant differences in the results before and after cool down for each tank or between tanks or if other anomalies are observed, an investigation is to be carried out and additional testing such as differential pressure, thermographic or acoustic emissions testing should be carried out as necessary
- the values recorded should be used as reference for future assessment of secondary barrier tightness.

**202** For containment systems with welded metallic secondary barriers, a tightness test after initial cool down is not required.

## SECTION 15 ADDITIONAL REQUIREMENTS FOR CERTAIN CARGOES

### A. General Requirements

#### A 100 Application

**101** The provisions of this section are applicable where specific reference is made in the *List of Cargoes*. The requirements may be constructional or operational or both dependent on the particular cargo. It is assumed that these operational requirements are complied with during operation of the ship.

#### A 200 Materials

**201** Materials as listed in 202 to 207, shall not be used for cargo tanks and associated pipelines, valves, fittings and other items of equipment when reference is made in the *List of Cargoes*.

**202** Mercury, copper and copper alloys and zinc.

**203** Copper, silver, mercury, magnesium and other acetylide-forming metals.

**204** Aluminium and aluminium alloys.

**205** Copper, copper alloys, zinc or galvanized steel.

**206** Aluminium or copper or alloys of either.

**207** Copper and copper bearing alloys with greater than 1% copper.

#### A 300 Independent tanks

**301** Products shall be carried in independent tanks only.

**302** Products shall be carried in independent tanks type C. The cargo containment systems 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. The design pressure of the cargo tank shall take into account any padding pressure and/or vapour discharge unloading pressure.

#### A 400 Not used

#### A 500 Refrigeration systems

**501** Only the indirect system described in Sec.7 A207 may be used.

**502** For ships carrying products which readily form dangerous peroxides, recondensed cargo is not allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:

- using the indirect system described in Sec.7 A207 with the condenser inside the cargo tank, or
- using the direct system, the combined system or the indirect system described in Sec.7 A206 to A208 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 shall be added upstream of such a place.

**503** If the ship shall carry consecutive cargoes of such products as mentioned in 502, with a ballast passage between, all uninhibited liquid shall be removed prior to the ballast voyage. If a second cargo shall be carried between such consecutive cargoes, the reliquefaction system shall be thoroughly drained and purged before loading the second cargo. Purging shall be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps shall be taken to ensure that polymers or peroxides do not accumulate in the ship's system.

#### A 600 Deck cargo piping

**601** 100% radiography of all butt welded joints in cargo piping exceeding 75.0 mm in diameter is required.

#### A 700 Bow or stern loading and discharge lines

**701** Bow or stern loading and discharging lines shall not be led past accommodation, service or control station spaces.

**702** Bow or stern loading and discharging lines shall not be used for the transfer of toxic cargoes, unless specifically approved by the Society.

#### A 800 Exclusion of air from vapour spaces

**801** Air shall be removed from the cargo tanks and associated piping before loading and then subsequently excluded by:

- 1) introducing inert gas to maintain a positive pressure. Storage or production capacity of the inert gas shall be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of the inert gas is at no time to be greater than 0.2% by volume, or
- 2) control of cargo temperature such that a positive pressure is maintained at all times.

#### A 900 Moisture control

**901** For gases which are non-flammable and may become corrosive or react dangerously with water, moisture control is required to ensure that cargo tanks are dry before loading and that during discharge, dry air or cargo vapour shall be introduced to prevent negative pressures. For the purposes of these requirements dry air is air which has a dewpoint of  $-45^{\circ}\text{C}$  or below at atmospheric pressure.

#### A 1000 Permanently installed toxic gas detectors

**1001** Gas sampling lines shall not be led into or through gas-safe spaces. Alarms referred to in Sec.13 B302 shall be activated when the vapour concentration reaches the threshold limiting value.

**1002** The alternative of using portable equipment in accordance with Sec.13 B303 is not permitted.

#### A 1100 Flame screens on vent outlets

**1101** Cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type when carrying a cargo referenced to in this section. Due attention shall be paid in the design of flame screens and vent heads to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Ordinary protection screens shall be fitted after removal of the flame screens.

#### A 1200 Maximum allowable quantity of cargo per tank

**1201** When carrying a cargo referenced to in this section, the quantity of the cargo shall not exceed  $3\,000\text{ m}^3$  in any one tank.

### B. Additional Requirements for Some Liquefied Gases

#### B 100 Ethylene oxide

**101** For the carriage of ethylene oxide the requirements of 800 apply, with the additions and modifications as given in this section.

**102** Deck tanks shall not be used for the carriage of ethylene oxide.

**103** Stainless steels types 416 and 442 as well as cast iron shall not be used in ethylene oxide cargo containment and piping systems.

**104** Before loading, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been ethylene oxide, propylene oxide or mixtures of these products. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.

**105** Ethylene oxide shall be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps shall comply with 813.

**106** Ethylene oxide shall be carried refrigerated only and maintained at temperatures of less than 30°C.

**107** Pressure relief valves shall be set at a pressure of not less than 5.5 bar gauge. The maximum set pressure shall be specially approved by the Society.

**108** The protective padding of nitrogen gas as required by 823 shall be such that the nitrogen concentration in the vapour space of the cargo tank will at no time be less than 45% by volume.

**109** Before loading and at all times when the cargo tank contains ethylene oxide liquid or vapour, the cargo tank shall be inerted with nitrogen.

**110** The water spray system required by 825 and that required by Sec.11 B300 shall operate automatically in a fire involving the cargo containment system.

**111** A jettisoning arrangement shall be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

### **B 200 Methylacetylene-propadiene mixtures**

**201** Methyl acetylene-propadiene mixtures shall be suitably stabilized for transport.

**202** A ship carrying methyl acetylene-propadiene mixtures is preferably to have an indirect refrigeration system as specified in Sec.7 A207. Alternatively, a ship not provided with indirect refrigeration may utilize direct vapour compression refrigeration subject to pressure and temperature limitations depending on the composition. For the example compositions given in the IGC Code, the features in 203 to 207 shall be provided.

**203** A vapour compressor that does not raise the temperature and pressure of the vapour above 60° and 17.5 bar gauge during its operation, and that does not allow vapour to stagnate in the compressor while it continues to run.

**204** Discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor shall have:

- 1) Two temperature actuated shutdown switches set at 60°C or less.
- 2) A pressure actuated shutdown switch set to operate at 17.5 bar or less.
- 3) A safety relief valve set to relieve at 18.0 bar gauge or less.

**205** The relief valve required by 204.3 shall vent to a mast meeting Sec.9 B207, B208, B209, B212 and B213 and shall not relieve into the compressor suction line.

**206** An alarm that sounds in the cargo control station and in the wheelhouse when a high pressure switch, or a high temperature switch operates.

**207** The piping system, including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixtures shall be either independent (as defined in Sec.1 B122) or separate (as defined in Sec.1 B133) from piping and refrigeration systems for other tanks. This segregation applies to all liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.

### **B 300 Nitrogen**

**301** Materials of construction and auxiliary equipment, such as insulation, shall 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. Due consideration shall be given to ventilation in such areas where condensation might occur to avoid the stratification of oxygen enriched atmosphere.

### **B 400 Ammonia**

**401** 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 402 to 408 shall be taken, as appropriate.

**402** Where carbon-manganese steel is used, cargo tanks, process pressure vessels and cargo piping shall be made of fine-grained steel with a specified minimum yield strength not exceeding 355 N/mm<sup>2</sup> and with an actual yield strength not exceeding 440 N/mm<sup>2</sup>. One of the following constructional or operational measures shall also be taken:

- 1) Lower strength material with a specified minimum tensile strength not exceeding 410 N/mm<sup>2</sup> shall be used.
- 2) Cargo tanks, etc., shall be post-weld stress relief heat treated.
- 3) Carriage temperature shall be maintained preferably at a temperature close to the product's boiling point of -33°C but in no case at a temperature above -20°C.
- 4) The ammonia shall contain not less than 0.1% w/w water.

**403** If carbon-manganese steels with higher yield properties are used other than those specified in 402 the completed cargo tanks, piping, etc., shall be given a post-weld stress relief heat treatment.

**404** Process pressure vessels and piping of the condensate part of the refrigeration system shall be given a post-weld stress relief heat treatment when made of materials mentioned in 401.

**405** The tensile and yield properties of the welding consumables shall exceed those of the tank or piping material by the smallest practical amount.

**406** Nickel steel containing more than 5% nickel and carbon-manganese steel not complying with the requirements of 402 and 403 are particularly susceptible to ammonia stress corrosion cracking and shall not be used in containment and piping systems for the carriage of this product.

**407** Nickel steel containing not more than 5% nickel may be used provided the carriage temperature complies with the requirements specified in 402.3.

**408** 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 as a func-

tion of the carriage temperature  $T$  in Table B1.

$T$ (°C)	$O_2$ (% v/v)
-30 and below	0.90
-20	0.50
-10	0.28
0	0.16
+10	0.10
+20	0.05
+30	0.03

Oxygen percentages for intermediate temperatures may be obtained by linear interpolation.

### **B 500 Vinyl chloride monomer**

**501** In case no or insufficient inhibitor has been added, any inert gas used for the purposes of A801 shall not contain more oxygen than 0.1%. Samples of the inert atmosphere in cargo tanks and cargo piping shall be analysed prior to loading. When vinyl chloride monomer is carried, a positive pressure is always to be maintained in the tanks, also during ballast voyages between successive carriages.

### **B 600 Chlorine**

**601** The capacity of each tank shall not exceed 600 m<sup>3</sup> and the total capacity of all cargo tanks shall not exceed 1 200 m<sup>3</sup>.

**602** The tank design vapour pressure  $p_0$  of the cargo tanks shall not be less than 13.5 bar (see also A302).

**603** Parts of tank protruding above the upper deck shall be provided with protection against thermal radiation taking into account total engulfment by fire.

**604** Each tank shall be provided with two safety relief valves. A bursting disc of appropriate material shall be installed between the tank and the safety relief valves. The rupture pressure of the bursting disc shall be 1 bar lower than the opening pressure of the safety relief valve, which shall be set at the design vapour pressure of the tank but not less than 13.5 bar. The space between the bursting disc and the relief valve shall be connected through an excess flow valve to a pressure gauge and a gas detection system. Provision shall be made to keep this space at or near the atmospheric pressure during normal operation.

**605** Outlets from safety relief valves shall 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 shall be led through the absorption plant to reduce the gas concentration as far as possible.

The relief valve exhaust line shall 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.

**606** Cargo discharge shall 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 shall not exceed 10.5 bar. Cargo discharge compressors or on deck pumps on board ships will not be accepted.

**607** The design pressure of the cargo piping system shall be not less than 21 bar. The internal diameter of the cargo pipes shall not exceed 100 mm.

Only pipe bends will be accepted for compensation of pipe line thermal movement. The use of flanged joints shall be restricted to a minimum, and when used the flanges shall be of the weld-neck type with tongue and groove.

**608** Relief valves of the cargo piping system shall discharge to the absorption plant.

**609** The cargo tanks and cargo piping systems shall be made of steel suitable for the cargo and for a temperature of -40°C, even if a higher transport temperature is intended to be used.

The tanks shall be thermally stress relieved. Mechanical stress relief will not be accepted as an equivalent.

**610** The ship shall be provided with a chlorine absorbing plant with connections to the cargo piping system and the cargo tanks. The absorbing plant shall be capable of neutralizing at least 2% of the total cargo capacity at a reasonable absorption rate.

**611** During the gas freeing of cargo tanks, vapours shall not be discharged to the atmosphere.

**612** As gas detecting system shall be provided capable of monitoring chlorine concentrations of at least 1 ppm by volume. Suction points shall be located:

- near the bottom of the hold spaces
- in the pipes from the safety relief valves
- at the outlet from the gas absorbing plant
- at the inlet to the ventilation systems for the accommodation, service, machinery spaces and control stations
- on deck at the forward end, in the middle and at the aft end of the cargo area. (These points are only for use during cargo handling and gas freeing operations.)

The gas detection system shall be provided with audible and visual alarm with a set point of 5 ppm.

**613** Each cargo tank shall be fitted with a high pressure alarm giving audible alarm at a pressure equal to 10.5 bar.

**614** The enclosed space required by Sec.19 C105 shall be easily and quickly accessible from the open deck and the accommodation and shall be capable of being rapidly closed gas-tight. Access to this space from the deck and the remainder of the accommodation shall be by means of an air lock. The space shall 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 four hours. One of the decontamination showers required by Sec.19 C103 shall be located near the air lock to the space.

**615** The maximum cargo tank filling limit shall be determined according to Sec.17 A102 and Sec.17 A105.1.

**616** The chlorine content of the gas in the vapour space of the cargo tank after loading shall be greater than 80% by volume.

#### **Guidance note:**

National regulations may require that chlorine is carried in the refrigerated state at a specified maximum pressure.

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### **B 700 Diethyl Ether and Vinyl Ethyl Ether**

**701** The cargo shall be discharged only by deepwell pumps or by hydraulically operated submerged pumps. These pumps shall be of a type designed to avoid liquid pressure against the shaft gland.

**702** Inert gas displacement may be used for discharging cargo from independent tanks type C provided the cargo system is designed for the expected pressure.

### **B 800 Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight**

**801** Products transported under the provision of this section shall be acetylene free.

**802** Unless cargo tanks are properly cleaned, these products shall not be carried in tanks which have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:

- ammonia, anhydrous and ammonia solutions
- amines and amine solutions
- oxidizing substances (e.g. chlorine).

**803** Before carrying these products, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been propylene oxide or ethylene oxide propylene oxide mixtures. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.

**804** In all cases the effectiveness of cleaning procedures for tanks and associated pipework shall be checked by suitable testing or inspection to ascertain that no trace of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.

**805** Tanks shall be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, including heavy rust deposits and any visible structural defects. When cargo tanks are in continuous service for these products, such inspections shall be performed at intervals of not more than two years.

**806** Tanks for the carriage of these products shall be of steel or stainless steel construction.

**807** Tanks which have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

**808** All valves, flanges, fittings and accessory equipment shall be of a type suitable for use with these products and shall be constructed of steel or stainless steel or other material acceptable to the Society. The chemical composition of all material used shall be submitted to the Society for approval prior to fabrication. Discs or disc faces, seats and other wearing parts of valves shall be made of stainless steel containing not less than 11% chromium.

**809** Gaskets shall be constructed of material which do not react with, dissolve in or lower the auto-ignition temperature of these products and which are fire resistant and possess adequate mechanical behaviour. The surface presented to the cargo shall 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 Society.

**810** Insulation and packing if used, shall be of a material which does not react with, dissolve in, or lower the auto-ignition temperature of these products.

**811** The following materials are generally found unsatisfactory for gaskets, packing and similar uses in containment systems for these products and would require testing before being approved by the Society:

- neoprene of natural rubber if it comes in contact with the products
- materials containing oxides of magnesium such as mineral wools.

The use of asbestos is generally prohibited (see Pt.4 Ch.1 Sec.2 A200).

**812** Filling and discharge piping shall extend to within 100 mm of the bottom of the tank or any sump pit.

**813** *Loading and discharging*

- 1) The products shall 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 shall be independent of all other containment systems.
- 2) During discharging operations, the pressure in the cargo

tank shall be maintained above 0.07 bar.

- 3) The cargo shall be discharged only by deepwell pumps, hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump shall be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

**814** Tanks carrying these products shall be vented independently of tanks carrying other products. Facilities shall be provided for sampling the tank contents without opening the tank to atmosphere.

**815** Cargo hoses used for transfer of these products shall be marked

**“FOR ALKYLENE OXIDE TRANSFER ONLY.”**

**816** Hold spaces shall 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 shall be maintained below 2%. Portable sampling equipment is satisfactory.

**817** Prior to disconnecting shore-lines, the pressure in liquid and vapour lines shall be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines shall not be discharged to atmosphere.

**818** Tanks shall be designed for the maximum pressure expected to be encountered during loading, conveying and discharging cargo.

**819** Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0.6 bar and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than 1.2 bar shall have a cooling system to maintain the cargo below the reference temperature. For reference temperature see Sec.17 A105.

**820** Pressure relief valve settings shall not be less than 0.2 bar and for type C independent cargo tanks not greater than 7.0 bar for the carriage of propylene oxide and not greater than 5.3 bar for the carriage of ethylene oxide-propylene oxide mixtures.

**821** *Piping segregation*

- 1) The piping system for tanks to be loaded with these products shall 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 Sec.1 B122, the required piping separation shall 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.
- 2) The products shall be transported only in accordance with cargo handling plans that have been approved by the Society. Each intended loading arrangement shall be shown on a separate cargo handling plan. Cargo handling plans shall 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 shall be kept onboard the ship. The International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shall be endorsed to include reference to the approved cargo handling plans.
- 3) Before loading the product, certification verifying that the required piping separation has been achieved shall be obtained from a responsible person acceptable to the port Administration and carried on board the ship. Each connection between a blank flange and pipeline flange shall be fitted with a wire and seal by the responsible person to

ensure that inadvertent removal of the blank flange is impossible.

**822** The maximum allowable tank loading limits for each cargo tank shall 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 Society. A copy of the list shall be permanently kept on board by the master.

**823** The cargo shall be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system shall be installed to prevent the tank pressure falling below 0.07 bar in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system. Sufficient nitrogen shall be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9% v/v) shall be used for padding. 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.

**824** The cargo tank vapour space shall be tested prior to and after loading to ensure that the oxygen content is 2% (v/v) or less.

**825** A water spray system of sufficient capacity shall be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles shall be such as to give a uniform distribution rate of 10 l/m<sup>2</sup> per minute. The water spray system shall be capable of both local and remote manual operation and the arrangement shall ensure that any spilled cargo is washed away. Remote manual operation shall be arranged such that remote starting of pumps supplying water spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected. Additionally, a water hose with pressure to the nozzle, when atmospheric temperatures permit, shall be connected ready for immediate use during loading and unloading operations.

#### **B 900 Isopropylamine and monoethylamine**

**901** Separate piping systems shall be provided as defined in Sec.1 B133.

## SECTION 16 GAS OPERATED PROPULSION MACHINERY

### A. General

#### A 100 Application

**101** Methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of category A and in such spaces may be utilized only in boilers, inert gas generators, combustion engines and gas turbines.

**102** These provisions do not preclude the use of gas fuel for auxiliary services in other locations, however, such services and locations shall be subject to special consideration by the Society.

**103** Machinery built for gas operation shall satisfy the requirements as given in Pt.4 Ch.7 and Pt.4 Ch.2 and is in addition to satisfy the requirements in this section. The regulations apply especially to boiler and diesel engine plants, but may also be used for gas turbines to the extent they are applicable.

**104** Alarm and safety systems shall comply with the requirements in Pt.4 Ch.9.

#### A 200 Documentation

**201** The following plants and particulars shall be submitted for approval:

- description of installation
- arrangement of engine room installation
- arrangement of piping for gas and fuel oil
- arrangement of gastight boiler casing with funnel
- arrangement of ventilation
- details showing burner equipment for gas or fuel oil for burners and combustion equipment for engines
- arrangement and details of installation for preparation of gas before combustion.

Further drawings may be required, if necessary, to evaluate the safety of the gas firing system.

**202** For requirements for documentation of instrumentation and automation, including computer based control and monitoring, see Sec.1.

### B. Gas Supply to Boilers and Engines, Arrangement of Engine and Boiler Rooms. Electrical Equipment

#### B 100 Gas make-up plant and related equipment

**101** The installation for the suction of gas from cargo tanks shall be such that it effectively prevents vacuum in the cargo tanks that may arise due to the suction of gases.

**102** The gas in the supply lines shall have a temperature not lower than the ambient temperature.

**103** All equipment (heaters, compressors, filters, etc.) for making-up the gas for its use as fuel, and the related storage tanks shall be located in the cargo area. If the equipment is in an enclosed space the space shall be ventilated according to Sec.10 and be equipped with a fixed fire extinguishing system according to Sec.11 B300 and with a gas detection system according to Sec.13 B300 as applicable.

**104** The compressors shall be capable of being remotely stopped from a position which is always and easily accessible, and also from the engine room. In addition, the compressors shall be capable of automatically stopping when the suction pressure reaches a certain value depending on the set pressure

of the vacuum relief valves of the cargo tanks. The automatic shutdown device of the compressors shall have a manual resetting. Volumetric compressors shall be fitted with pressure relief valves discharging into the suction line of the compressor. The size of the pressure relief valves shall be determined in such a way that, with the delivery valve kept closed, the maximum pressure does not exceed by more than 10% the maximum working pressure. The requirements of Sec.6 C403 apply to these compressors.

**105** 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 shall be located in the cargo area. Provisions shall be made to detect and alarm the presence of gas in the tank. The vent outlet shall be in a safe position and fitted with a flame screen.

**106** The gas pressure in the supply line to the engine or the burner shall be kept within the specified range at all actual loads.

**107** Pressure vessels in the gas fuel conditioning system shall comply with the requirements for cargo tanks type C in Sec.5. Piping shall comply with Sec.6.

#### B 200 Gas supply lines

**201** Gas fuel piping shall not pass through accommodation spaces, service spaces or control stations. Gas fuel piping may pass through or extend into other spaces provided they fulfil one of the following:

- 1) The gas piping shall be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms shall be provided to indicate a loss of inert gas pressure between the pipes.
- 2) The gas fuel piping shall be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the inner wall of this pipe or duct shall be equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour. The ventilation system shall be arranged to maintain a pressure less than the atmospheric pressure. The fan motors shall be placed outside the ventilated pipe or duct. The ventilation outlet shall be covered by a *protection screen* and placed in a position where no flammable gas-air mixture may be ignited. The ventilation is always to be in operation when there is gas fuel in the piping. Continuous gas detection shall be provided to indicate leaks and to alarm and subsequently shut down the gas fuel supply to the machinery space in accordance with 205 and 206. The master gas fuel valve required by 206 is to close automatically, if the required air flow is not established and maintained by the exhaust ventilation system.

**202** The double wall piping system or the ventilated pipe or duct provided for the gas fuel lines shall terminate at a ventilation hood or casing arranged to cover the areas occupied by flanges, valves, etc., and the gas fuel piping at the gas fuel utilization units, such as boilers, diesel engines or gas turbines. If this ventilation hood or casing is not served by the exhaust ventilation fan serving the ventilated pipe or duct as specified in 201.2, then it shall be equipped with an exhaust ventilation system and continuous gas detection shall be provided to indicate leaks and to alarm and subsequently shut down the gas fuel supply to the machinery space in accordance with 205 and 206. The master gas fuel valve required by 206 shall close au-

tomatically if the required air flow is not established and maintained by the exhaust ventilation system.

The ventilation hood or casing shall 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.

In the case of diesel engines with high pressure gas injection (> 200 bar) the arrangement of the ventilation hood may be omitted provided all gas lines and connecting flanges are completely encased in the outer piping or ducting.

**203** The ventilation air inlet and discharge for the required ventilation systems shall be respectively from and to a safe location.

**204** Gas detection systems provided in accordance with the requirements of 201.2 and 202 shall comply with applicable parts of Sec.13 B300.

**205** Alarm shall be given at:

- abnormal pressure in the gas fuel supply line
- gas concentration of maximum 30% of lower explosion limit in the vented duct (201.2), ventilation hood (202) or in the engine room
- failure of the valve control actuating medium.

**206** The main supply lines for gas shall be equipped with a manually operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined manually and automatically operated stop valve. The valves shall be situated in the part of the piping which is outside engine room or boiler room, and placed as near as possible to the installation for heating the gas. The valve is automatically to cut off the gas supply when:

- there is abnormal pressure in the supply line for gas, see 106
- the fire alarm onboard is sounded (with time delay)
- the engine room ventilation capacity on either supply or exhaust is reduced by more than 50% (with time delay)
- gas concentration of maximum 60% of the lower explosion limit in the vented duct (201.2) or ventilation hood (202) is detected.

The automatic master gas fuel valve shall be manually operable from a reasonable number of places in the engine room and from a room outside the engine casing.

**207** Each gas utilization unit shall be provided with a set of three automatic valves. Two of these valves shall be in series in the gas fuel pipe to the consuming equipment. The third valve shall be in a pipe that vents to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series. These valves shall be arranged so that the following conditions will cause the two gas fuel valves which are in series to close automatically and the vent valve to open automatically:

- the conditions specified in 206
- failure of the necessary forced draught
- loss of flame on boiler burners
- failure of the valve control actuating medium.

Alternatively, the function of 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. The three shut-off valves shall be arranged for manual reset.

**208** In the branch lines for the gas supply to each cylinder and burner, there shall be a screw-down non-return valve and a flame arrester. In the main gas supply pipelines before the boilers and the engines shall be mounted a gas control valve.

**209** It shall be clearly indicated on all shut-off valves wheth-

er the valves are open or closed.

**210** It shall be possible for the complete pipe system for gas supply, including ventilation ducts, hood and casing, to be gas-freed and air-freed effectively by means of inert gas.

Warning and notice plate shall be provided, which clearly indicates that gas-freeing shall not take place through a recently extinguished combustion chamber. Measures shall be taken to prevent ingress of air through pipe connections between the gas supply pipe and the atmosphere.

**211** If the gas supply is shut off on account of release of an automatic valve, the gas supply shall not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect, shall be placed at the operating station for the shut-off valves in the gas supply lines.

**212** If a gas leak occurs, the gas fuel supply shall not be operated until the leak has been found and repaired. Instructions to this effect shall be placed in a prominent position in the machinery space.

**213** The gas supply lines outside the cargo area shall be designed for a pressure at least 50% higher than the normal working pressure. Both wall thickness and diameter of the piping, as well as the arrangement, shall be such that the pipes will not suffer damage from external loading to which they may be subjected. The piping shall, as far as practicable, have welded joints. Those parts of the gas fuel piping, which are not enclosed in a ventilated pipe or duct according to 201 and are on the open deck outside the cargo area shall have full penetration butt welded joints and shall be fully radiographed.

The material in the inner piping shall satisfy the requirements given in Pt.4 Ch.6 for pipes in class I.

The gas supply lines shall be hydraulically tested in accordance with Pt.4 Ch.6 Sec.7. A tightness test is also to be carried out for the outer pipe or duct.

### **B 300 Arrangement of engine and boiler rooms, etc.**

**301** Combined boiler and engine rooms will be considered specially in each separate case with regard to ventilation and other safety precautions.

**302** Spaces in which gas fuel is utilized shall be fitted with a mechanical ventilation system and be arranged in such a way as to prevent the formation of dead spaces. Such ventilation to be particularly effective in the vicinity of electrical equipment and machinery or of other equipment and machinery which may generate sparks.

Such a ventilation system shall be separated from those intended for other spaces.

(IGC Code 16.2.1)

**303** The engine room and boiler room are each to have at least two completely independent exits.

**304** The engine and boiler room shall have to simple geometrical shape as possible.

**305** In engine room and boiler room where gas operation is used, there shall be gas detectors or suction points for such in all places where there is a danger that gas pockets may be formed. The gas detectors in engine room and boiler room shall not be incorporated in the ship's remaining gas detector system and shall comply with Sec.13 B300. For gas detectors or suction points for these, there is in addition to the alarm system mentioned in Sec.13 B300, to be arranged a readily audible alarm in the engine room and boiler room. This alarm shall give signal if any of these show a gas content of maximum 30% of the lower explosion limit.

The gas detector system shall be in continuous operation when the main shut-off valves for the gas system are open. The period shall not exceed 15 minutes with alternating readings taken from the various suction points.

## **B 400 Electrical equipment**

**401** The location of electrical equipment and the ventilation of spaces where electrical equipment is installed, are generally to be such that the possibility of gas accumulation in such spaces is a minimum. This particularly applies to equipment which produces sparks (e.g. switchboards and other switchgear such as motor starters, machines with sliprings or commutators). Alternatively, special requirements to enclosure and or separate ventilation of electrical equipment can be made, after consideration in each case.

**402** Electrical equipment located in the double wall pipe or duct specified in 201 shall be of the intrinsically safe type.

## **C. Gas Fired Boiler Installations**

### **C 100 Burners for gas firing**

**101** Boiler installations may have supply by boil-off fuel during low loading and manoeuvring conditions, if approved means of disposing of the excess steam are provided.

**102** The burners for gas shall be of such construction that they effectively maintain complete and stable combustion under all operating conditions.

**103** The burner systems shall be of dual fuel type, suitable to burn either oil fuel or gas fuel alone or oil and gas fuel simultaneously. Only oil fuel shall be used during manoeuvring and port operations unless automatic transfer from gas to oil burning is provided in which case the burning of a combination of oil and gas or gas alone may be permitted provided the system is demonstrated to the satisfaction of the Society.

#### **Guidance note:**

To demonstrate acceptability of dual fuel or gas only operation during manoeuvring, testing under varying loads should be carried out.

The details of the testing will depend on the design and functionality of the combustion control and burner management system.

As a guide, the following manoeuvring tests may be considered:

- From full ahead and “gas-only” or “dual fuel” mode, reduce stepwise to a load just above the auto change over limit to fuel only, and run at this load for approximately 3 min.
- Increase stepwise to full ahead.
- From full ahead, reduce directly to a load just above the limit for auto transfer to “fuel-only” and run at this load for approximately 3 min.
- Increase again directly to full ahead.
- From full ahead and “gas only” operation reduced stepwise to stop.
- Check auto transfer to dual fuel as applicable.
- After approximately 3 minutes stop, go to slow astern and increase stepwise to half astern.
- Run for approximately 3 minutes and then to stop.
- After 3 minutes stop, go direct to half ahead.

In addition to the above manoeuvring tests, demonstrations of auto transfer “gas only” to “dual fuel” and from “dual fuel” to “oil only” for various fault conditions should be carried out.

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It shall be possible to change over easily and quickly from gas fuel operation to oil fuel operation. Gas nozzles shall be fitted in such a way that gas fuel is ignited by the flame of the oil fuel burner. A flame scanner shall be installed and arranged to assure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained. On the pipe of each gas burner a manually operated shut-off valve shall be fitted. An installation shall be provided for purging the gas supply piping to the burners by means of inert gas or steam, after the extinguishing of these burners.

**104** Alarm devices shall be fitted in order to monitor a possible decrease in liquid fuel oil pressure or a possible failure of the related pumps.

**105** Arrangements shall be made that, in case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the boilers are automatically purged before relighting. Arrangements are also to be made to enable the boilers to be manually purged and these arrangements shall be to the satisfaction of the Society.

**106** At the operating stations for the boilers, a readily visible signboard with the following instruction shall be posted:

**CAUTION:**

**NO BURNER TO BE FIRED BEFORE**

**THE FURNACE HAS BEEN PROPERLY PURGED**

### **C 200 Construction of the boilers**

**201** The boilers shall be so constructed that there is no danger that gas pockets will be formed in any place in the firing and flue gas part of the boiler.

**202** Each boiler shall have a separate flue gas line led up to the top of the funnel.

**203** Oxygen content in the flue gas line shall be indicated.

**204** Boilers for firing with gas shall be equipped with automatic regulation of air supply in order to attain complete combustion with a suitable quantity of excess air.

### **C 300 Monitoring systems**

**301** The extent of monitoring of gas fired boilers shall comply with the requirements specified in Pt.4 Ch.7 Sec.7 for oil fired boilers.

## **D. Gas-Operated Engine Installations**

### **D 100 General**

**101** For gas fuelled engine installations, see Pt.6 Ch.13.

For gas carriers with gas fuelled engine installations, other than steam driven LNG carriers, the class notation **GAS FUELLED** is mandatory.

## SECTION 17 FILLING LIMITS FOR CARGO TANKS

### A. Filling Limits for Cargo Tanks

#### A 100 General

**101** No cargo tanks shall have a higher filling limit (FL) than 98% at the reference temperature, except as permitted by 103.

**102** The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:

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

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 as specified in 101 or 103

$\rho_R$  = relative density of cargo at the reference temperature

$\rho_L$  = relative density of cargo at the loading temperature and pressure.

**103** The Society may allow a higher filling limit (FL) than the limit of 98% specified in 101 at the reference temperature taking into account the shape of the tank, arrangements of pressure relief valves, accuracy of liquid level and temperature gauging and the difference between the loading temperature and the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves.

**104** The Society may stipulate a lower filling limit than 98% at the reference temperature if the conditions in Sec.9 B203 are not fulfilled.

**105** For the purpose of this section only, *reference temperature* means:

- 1) The temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves when no cargo vapour pressure or temperature control as referred to in Sec.7 is provided.

- 2) The temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greater, when a cargo vapour pressure and temperature control system as referred to in Sec.7 A100, is provided. If this reference temperature would result in the cargo tank becoming liquid full before the cargo reaches a temperature corresponding to the vapour pressure of the cargo at the set pressure of the relief valves required in Sec.9 B200, an additional pressure relief system complying with Sec.9 B500 shall be fitted.

**106** The Society may allow type C tanks to be loaded according to the following formula provided that the tank vent system has been approved in accordance with Sec.9 B215:

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

LL = loading limit as specified in 102

FL = filling limit as specified in 101 or 103

$\rho_R$  = relative density of cargo at the highest temperature which the cargo may reach upon termination of loading, during transport, or at unloading, under the ambient design temperature conditions described in Sec.7 A103

$\rho_L$  = as specified in 102.

This paragraph does not apply to products requiring a type 1G ship.

#### A 200 Information to be provided to the master

**201** The maximum allowable tank filling limits for each cargo tank shall be indicated for each product which may be carried, for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Society. Pressures at which the pressure relief valves, including those valves required by Sec.9 B500 have been set shall also be stated on the list. A copy of the list shall be permanently kept on board by the master.

## SECTION 18 INERT GAS PLANTS

### A. General

#### A 100 Application

**101** The rules in this section apply to inert gas systems for inerting of cargo piping systems, cargo containment systems and void spaces in the cargo area, if fitted.

#### A 200 General

**201** The applicable requirements of Ch.3 Sec.11 A200, A300, B, C, D and E apply in addition to those given in 202 to 205. Certification requirements for components in inert gas systems and nitrogen systems based on separation of air are given in Table A1 and Table A2.

**Guidance note 1:**

The following requirements from Ch.3 Sec.11 are considered applicable: A200, B100, C100, C206, C207, C600, D101, D400, D601, D604, E101, E201, E301, E302, E304.

However, the requirement to deck water seal referred to in Ch.3 Sec.11 C600 is not applicable to gas carriers.

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Two non return valves in series or equivalent solutions will be accepted when no permanent connection is arranged to cargo tank or hold space.

**Guidance note 2:**

Gas carriers built also to carry oil with flashpoint less than 60°C should comply with the inert gas requirements of SOLAS as for oil tankers, Ch.3 Sec.11 or for chemical tankers, Ch.4 Sec.16.

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**Guidance note 3:**

For further reference, see IACS unified requirements F20 on inert gas systems.

Requirements for nitrogen generator systems: F20.3.3, F20.4.4, F20.4.5, F20.4.6, F20.4.9, F20.4.11, F20.4.12, F20.4.14, F20.4.15, F20.4.16, F20.4.17, F20.4.18, F20.5.3, and

For nitrogen membrane systems the following requirements applies: F20.4.8, F20.4.10, F20.4.13, F20.4.16 (1-4), F20.4.17, and F20.4.18.

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**202** Redundancy of inert gas system is not required.

**203** Where inert gas is made by an onboard process of fractional distillation of air which involves the storage of the cryogenic, liquefied nitrogen for subsequent release, the liquefied

gas entering the storage vessel shall be monitored for traces of oxygen to avoid possible initial high oxygen enrichment of the gas when released for inerting purposes.

**204** Spaces containing inert gas generating plants shall have no direct access to accommodation, service or control station spaces, but may be located in machinery spaces or other spaces outside the cargo area. Two non-return valves or equivalent devices shall be fitted in the inert gas main in the cargo area. Inert gas piping shall not pass through accommodation, service or control station spaces.

When not in use, the inert gas system shall be made separate from the cargo system in the cargo area.

**205** Flame burning equipment for generating inert gas shall not be located within the cargo area. Special considerations may be given to the location of inert gas generating equipment using the catalytic combustion process.

**206** A continuous reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume subject to the requirements of Sec.15.

Table A1 Inert gas system		
Component	Certificate	Comment
Inert gas generator	NV	
Air blower	W	
Scrubber	W	
Cooling water pump for scrubber	W	
Refrigerant type drier	W	Pressure vessel, NV
Absorption drier	W	Pressure vessel, NV
Control & monitoring system	NV or T	
NV = DNV product certificate, W = Maker's (Works) certificate, T = Type approval		

Table A2 Nitrogen System.		
Component	Certificate	Comment
Membrane separation vessels	NV	Pressure vessels
Air compressor	W	NV if power > 200kW
Control & monitoring system	W	
NV = DNV product certificate, W = Maker's (Works) certificate, T = Type approval		

## SECTION 19 PERSONNEL PROTECTION

### A. General

#### A 100 Protective equipment

**101** Suitable protective equipment including eye protection shall be provided for protection of crew members engaged in loading and discharging operations, taking into account the character of the products.

#### A 200 Safety equipment

**201** Sufficient, but not less than two complete sets of safety equipment in addition to the firefighter's outfits required by Sec.11 A200 each permitting personnel to enter and work in a gas-filled space, shall be provided.

**202** One complete set of safety equipment shall consist of:

- 1) One self-contained air-breathing apparatus, not using stored oxygen, having a capacity of at least 1,200 l of free air.
- 2) Protective clothing, boots, gloves and tight-fitting goggles.
- 3) Steel-cored rescue line with belt.
- 4) Explosion-proof lamp.

**203** An adequate supply of compressed air shall be provided and shall consist either of:

- 1) One set of fully charged spare air bottles for each breathing apparatus required by 201;  
a special air compressor suitable for the supply of high-pressure air of the required purity; and  
a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by 201, or
- 2) Fully charged spare air bottles with a total free air capacity of at least 6,000 l for each breathing apparatus required by 101.

**204** Alternatively, the Society may accept a low-pressure air line system with hose connection suitable for use with the breathing apparatus required by 201. This system should provide sufficient high-pressure air capacity to supply, through pressure reduction devices, enough low-pressure air to enable two men to work in a gas-dangerous space for at least 1 hour without using the air bottles of the breathing apparatus. Means should be provided for recharging the fixed air bottles and the breathing apparatus air bottles from a special air compressor suitable for the supply of high-pressure of the required purity.

**205** Protective equipment required in 101 and safety equipment required in 201 shall be kept in suitable, clearly marked lockers located in readily accessible places.

**206** The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection recorded in the ship's log-book, and inspected and tested by an expert at least once a year.

### B. First-aid Equipment

#### B 100 General

**101** A stretcher which is suitable for hoisting an injured per-

son from spaces below deck shall be kept in a readily accessible location.

**102** The ship shall have on board medical first-aid equipment, including oxygen resuscitation equipment and antidotes for cargoes to be carried, based on the guidelines developed by IMO.

#### Guidance note:

Reference is made to the Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG), which provides advice on the treatment of casualties in accordance with the symptoms exhibited as well as equipment and antidotes that may be appropriate for treating the casualty.

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### C. Personnel Protection Requirements for Individual Products

#### C 100 General

**101** Provisions of 100 are applicable to ships carrying products for which those paragraphs are listed in column 'f' in the Table A1 of Appendix A.

**102** Respiratory and eye protection suitable for emergency escape purposes shall be provided for every person on board subject to the following:

- 1.1 Filter type respiratory protection is unacceptable.
- 1.2 Self-contained breathing apparatus is normally to have a duration of service of at least 15 min.
- 2 Emergency escape respiratory protection shall not be used for fire-fighting or cargo handling purposes and should be marked to that effect.
- 3 Two additional sets of the above respiratory and eye protection shall be permanently located in the navigating bridge.

**103** Suitably marked decontamination showers and eyewash shall be available on deck in convenient locations. The showers and eyewash shall be operable in all ambient conditions.

(IGC Code 14.4.3)

#### Guidance note:

Decontamination shower and eye wash units should be located on both sides of the ship in the cargo manifold area and in way of the entrance to the compressor room.

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**104** In ships of a cargo capacity of 2 000 m<sup>3</sup> and over, two complete sets of safety equipment shall be provided in addition to the equipment required by Sec.11 A200 and A201. At least three spare charged air bottles shall be provided for each self-contained air-breathing apparatus required above.

**105** Personnel shall be protected against the effects of a major cargo release by the provision of a space within the accommodation area designed and equipped to the satisfaction of the Society.

**106** For certain highly dangerous products, cargo control room shall be of the gas-safety type only.

## APPENDIX A LIST OF CARGOES (TANKER FOR LIQUEFIED GAS)

### A. List of Cargoes

#### A 100 General

**101** Table A1 provides a summary of some minimum construction requirements for the specific cargoes.

#### A 200 Marking

**201** Cargoes marked with \* in the first column of Table A1, are cargoes covered by IMO International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

**202** Cargoes marked with + in the first column of Table A1, are cargoes which are covered by both IMO International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and IMO International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk.

#### A 300 Abbreviations

*Gauging systems, type permitted (column c):*

- I** Indirect or closed as described in Sec.13 B102 and 103.
- C** Indirect or closed, as described in Sec.13 B102, 103 and 104.
- R** Indirect, closed or restricted, as described in Sec.13 B102, Sec.13 B103, Sec.13 B104 and Sec.13 B105.

*Vapour detection required (column d):*

- F** Flammable vapour detection.
- T** Toxic vapour detection.
- O** Oxygen analyser.

	Name and chemical formula	a	b	c	d	e	f
		Ship type	D Liquid density (kg/m <sup>3</sup> ).	Gauging system	Vapour detection	Control of vapour space within tank	Remarks. Special requirements
*	ACETALDEHYDE CH <sub>3</sub> CHO	2G/2PG	(20.8°C) 780	C	F + T	Inert	Sec.15 A501, A702, A801.1, Sec.19 C103, C104
*	AMMONIA (ANHYDROUS) NH <sub>3</sub>	2G/2PG	(- 33.4°C) 680	C	T	-	Sec.15 A202, A702, B400, Sec.19 C102, C103, C104
*	BUTADIENE 1.3 (inhibited) CH <sub>2</sub> CHCHCH <sub>2</sub>	2G/2PG	(- 4.5°C) 650	R	F+T	-	Sec.15 A203, A502, A503, A800
*	BUTANE C <sub>4</sub> H <sub>10</sub>	2G/2PG	(- 0.5°C) 600	R	F	-	
*	BUTANE/PROPANE mixtures	2G/2PG		R	F	-	
*	BUTYLENES	2G/2PG	(- 6.3; 3.7°C) 630; 640	R	F	-	
*	CARBON DIOXIDE	3G		C	-		
*	CHLORINE Cl <sub>2</sub>	1G	(- 34°C) 1 560	I	T	Dry	Sec.15 A501, A600, A700, A900, A1000, B600, Sec.19 C
*	DICHLOROMONOFUOROMETHANE CHFCl <sub>2</sub> Refrigerant gas (R-21)	3G	(8.9°C) 1480	R	-	-	
*	DICHLOROTETRAFLUROETHANE C <sub>2</sub> F <sub>4</sub> Cl <sub>2</sub> Refrigerant gas (R-114)	3G	(3.8°C) 1 510	R	-	-	
+	DIETHYL ETHER C <sub>2</sub> H <sub>5</sub> O C <sub>2</sub> H <sub>5</sub>	2G/2PG	(34.6°C) 640	C	F + T	Inert	Sec.15 A207, A301, A702, A801.1, A1100, A1200, B700, Sec.19 C102, C103
	DIMETHYL ETHER	2G/2PG	(-23°C) 668	C	F + T	-	
*	DIMETHYLAMINE (CH <sub>3</sub> ) <sub>2</sub> NH	2G/2PG	(6.9°C) 670	C	F + T	-	Sec.15 A202, A702, Sec.19 C102, C103, C104
*	ETHANE C <sub>2</sub> H <sub>6</sub>	2G	(- 88°C) 550	R	F	-	

Table A1 Summary of some minimum construction requirements for special cargoes (Continued)							
	Name and chemical formula	a	b	c	d	e	f
		Ship type	D Liquid density (kg/m <sup>3</sup> ).	Gauging system	Vapour detection	Control of vapour space within tank	Remarks. Special requirements
*	ETHYL CHLORIDE CH <sub>3</sub> CH <sub>2</sub> Cl	2G/2PG	(12.4°C) 920	R	F + T	-	Sec.15 A702
*	ETHYLENE C <sub>2</sub> H <sub>4</sub>	2G	(-104°C) 560	R	F	-	
*	ETHYLENE OXIDE (CH <sub>2</sub> ) <sub>2</sub> O	1G	(10.4°C) 870	C	F + T	Inert	Sec.15 A203, A302, A501, A600, A701, A801.1, B100, Sec.19 C102, C103, C104, C106
+	ETHYLENE OXIDE/PROPYLENE OX- IDE mixture with ethylene oxide content of not more than 30% by weight	2G/2PG	-	C	F + T	Inert	Sec.15 A301, A501, A702, A801.1, A1100, A1200, B800, Sec.19 C103
+	ISOPRENE(inhibited) CH <sub>2</sub> C(CH <sub>3</sub> )CHCH <sub>2</sub>	2G/2PG	(34°C) 680	R	F	-	Sec.15 A1100, Sec.19 C103
+	ISOPROPYLAMINE (CH <sub>3</sub> ) <sub>2</sub> CHNH <sub>2</sub>	2G/2PG	(33°C) 710	C	F + T	-	Sec.15 A205, A702, A1100, A1200, B900, Sec.19 C102, C103
*	METHANE CH <sub>4</sub> (LNG)	2G	(-164°C) 420	C	F	-	
*	METHYL ACETYLENE - PROPADIENE MIXTURE	2G/2PG		R	F	-	Sec.15 B200
*	METHYL BROMIDE CH <sub>3</sub> Br	1G	1 730	C	F + T	-	Sec.15 A302, A501, A600, Sec.19 C
*	METHYL CHLORIDE CH <sub>3</sub> Cl	2G/2PG	920	C	F + T	-	Sec.15 A204, A702
*	MONOCHLORODIFLUOROMETHANE CHClF <sub>2</sub> Refrigerant gas (R-22)	3G	(- 42°C) 1 420	R	-	-	
*	MONOCHLOROTETRAFLUOR- OETHANE C <sub>2</sub> HF <sub>4</sub> Cl Refrigerant gas	3G		R	-	-	
*	MONOCHLOROTRIFLUOROMETH- ANE CF <sub>3</sub> Cl Refrigerant gas (R-13)	3G	(-81.4°C) 1 520	R	-	-	
+	MONOETHYLAMINE C <sub>2</sub> H <sub>2</sub> NH <sub>2</sub>	2G/2PG	(16.6°C) 690	C	F + T	-	Sec.15 A202, A301, A702, A1100, A1200, B900, Sec.19 C102, C103, C104
*	NITROGEN N <sub>2</sub>	3G	(-196°C) 808	C	O	-	Sec.15 B300
+	PENTANES (all isomers)	2G/2PG	630	R	F	-	Sec.15 A1100, Sec.19 C104
+	PENTENES (all isomers)	2G/2PG	650 Sec.19 C104	R	F	-	Sec.15 A1100, Sec.19 C104
*	PROPANE C <sub>3</sub> H <sub>8</sub>	2G/2PG	(-42.3°C) 590	R	F	-	
*	PROPYLENE C <sub>3</sub> H <sub>6</sub>	2G/2PG	(- 47.7°C) 610	R	F	-	
+	PROPYLENE OXIDE CH <sub>3</sub> CHOCH <sub>2</sub>	2G/2PG	860	C	F + T	Inert	Sec.15 A301, A501, A702, A801.1, A1100, A1200, B800, Sec.19 C103

<b>Table A1 Summary of some minimum construction requirements for special cargoes (Continued)</b>							
	<i>Name and chemical formula</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>
		<i>Ship type</i>	<i>D Liquid density (kg/m<sup>3</sup>).</i>	<i>Gauging system</i>	<i>Vapour detection</i>	<i>Control of vapour space within tank</i>	<i>Remarks. Special requirements</i>
*	SULPHUR DIOXIDE (inhibited) SO <sub>2</sub>	1G	(-10°C) 1 460	C	T	Dry	Sec.15 A302, A600, A701, A900, A1000, Sec.19 C
*	VINYL CHLORIDE MONOMER CH <sub>2</sub> CHCl (inhibited)	2G/2PG	(- 13.9°C) 970	C	F + T	-	Sec.15 A203, A204, A502, A503, A702, A800, B500, Sec.19 C102, C103
+	VINYL ETHYL ETHER CH <sub>2</sub> CHOC <sub>2</sub> H <sub>5</sub> (inhibited)	2G/2PG	754	C	F + T	Inert	Sec.15 A203, A301, A702, A801.1, A1100, A1200, B700, Sec.19 C102, C103
+	VINYLDENE CHLORIDE C <sub>2</sub> H <sub>2</sub> CCl <sub>2</sub> (inhibited)	2G/2PG	1 250	R	F + T	Inert	Sec.15 A206, A702, A801.1, A1100, A1200, Sec.19 C102, C103